Could the notions of quantum geology and quantum biology make sense?

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Abstract

This article is an attempt to fuse the existing TGD inspired ideas about the geological and biological evolution of life on Earth to a single coherent whole. The strategy is to identify weak points of the existing vision and here the language models provide an extremely powerful tool.

The evolution of life on Earth encountered several bottlenecks. In the beginning, the generation of nitrogen atoms from N_2 molecules, having a very large binding energy, was made possible by the presence of volcanoes but soon it became ineffective. Bacteria invented the nitrogenase enzyme for which oxygen was a poison. Later bacteria invented oxygen breathing and photosynthesis releasing oxygen as a waste. This led to the Great Oxygenation Event meaning a catastrophe destroying most bacteria. Ways to avoid the destruction of nitrogenase were invented.

The sudden emergence of highly evolved multicellular life forms in Cambrian Explosion (CE) with almost no fossils intermediate between them and monocellulars is an unsolved mystery. It served as the starting point of the development of the TGD based view of biological and geological evolution of Earth. There is evidence that the continents of the Earth fit nicely together along the boundaries if the radius of the Earth is taken 1/2 of the recent radius. This inspires the proposal that CE involved a rapid expansion of the radius of Earth in a geologically short time interval and the multicellular life forms evolved in underground oceans before the CE.

In the sequel my goal is to develop an overall vision of the geological and biological ideas about the evolution of the Earth. The starting point is the explanation for the CE and the problem associated with it.

1. The contraction of the Earth radius by factor 1/2 implies the increase of the density by factor 8. In the framework of standard model physics implies a huge increase of pressure and temperature and life could not have evolved in underground water reservoirs if they could be even present. Large scale quantum coherence could however change the situation.

2. The liberated gravitational and atomic binding energies would have served as a metabolic energy increasing the value of h_{eff} (a measure for complexity) and given rise to phases of matter labelled by biologically important p-adic length scales. Assuming that repulsive Coulomb energies decreased and that the allowed p-adic integers k are primes, a simple scaling argument implies that biologically relevant p-adic length scales characterize the quantum coherence regions space-time sheets.

   The compression would have induced a Pollack effect, which transferred protons and possibly also other alkali ions from the silicate (SiO_4^{-4}) lattice of the mantle to the

gravitational magnetic body of the Earth characterized by a huge value of gravitational Planck constant $\hbar_{gr}$ so that the system became quantum coherent in astrophysical length scales. The dramatic reduction of the number of translational degrees of freedom implied that the pressure and temperature could remain in the physiological range and multicellular life could evolve in underground water reservoirs and emerge to the surface in Cambrian Explosion involving an expansion of the Earh radius by factor 2.

3. p-Adic length scale hypothesis allows to make the picture quantitative. For years ago, I considered the possibility of a phase transition reducing the p-adic size scale of atoms by factor 2. The p-adic length scale $L(k = 139)$ defining atomic size scale would have been reduced to $L(137) = L(139)/2$. This would have liberated a huge gravitational energy and thrown the surface layer out giving rise to the formation of the Moon. The liberated gravitational and atomic binding energies would have served as a metabolic energy increasing the value of h_{eff} (a measure for complexity) and generated phases of matter with long p-adic length scales. Assuming that repulsive Coulomb energies decreased and that the allowed p-adic integers k are primes, a simple scaling argument implies that biologically relevant p-adic length scales characterize the space-time sheets as quantum coherence regions.

4. The presence of gravitational quantum coherence motivates quantum model for the Earth as an elastic ball based on quantum harmonic oscillator characterized by $\hbar_{gr}$ coding Equivalence Principle and implying that the radii of harmonic oscillator states do not depend on the particle mass.

   The model suggests that the compression and expansion phases could have taken place in two steps. During the first step of the compression phase the particles of the upper mantle would have been transferred to lower harmonic oscillator states. During the second step this would have happened to the particles of the lower mantle. One of the key questions is whether the oceans were at the surface of Earth before CE or not: also this question I try to answer in the sequel.

   This picture provides a qualitative understanding of the geological evolution, including formation of old mountains before the first step of contraction and emergence of plate tectonics after it. Also oceans could have emerged already in the first step. The model explains why the tectonic plates for the oceanic crust differ from those for the continental crust.

Contents

1 Introduction

This article represents an attempt to fuse the existing TGD inspired ideas about the geological and biological evolution of life on Earth to a single coherent whole. The strategy is to identify weak points of the already existing vision and here the language models provide an extremely powerful tool.

Before continuing, I want to make it clear that I am not a professional biologist or geologist, I am just a thinker with basic education in theoretical physics. Therefore I must take a humble attitude and try to build an overall view from the evolution of life on the Earth and admit that these attempts are only sketches. Here Google Gemini has been extremely helpful by giving rather reliable responses to my amateurish prompts.

On the other hand, I must also make it clear that TGD leads to a new view of the evolution of life which in many respects is revolutionary. This probably induces a lot of aggression in academic researchers enjoying monthly salaries. My only goal is however not to irritate professionals: I just want to patiently communicate the new vision inspired by a single very far reaching idea almost half a century ago that led to the recent view of TGD. At the age of 75, I have no dreams of being any kind of guru.

1.1 About the chemical history of life

The evolution of life encountered several bottlenecks. In the beginning, the generation of nitrogen atoms from N_2 molecules, having a very large binding energy, was made possible by the presence of volcanoes but soon it became ineffective. Bacteria invented the nitrogenase enzyme for which oxygen was a poison. Later bacteria invented oxygen breathing and photosynthesis releasing oxygen as a waste. This led to the Great Oxygenation Event meaning a catastrophe destroying most bacteria. Ways to avoid the destruction of nitrogenase were invented.

The emergence of the basic molecules of life poses strong conditions on the atmosphere of the Earth.

1. Redox reactions, oxidation (combustion) and reduction are central to biology. They are encountered concretely when trying to understand the evolutionary history of life as seen by a biochemist and in attempts to to build a TGD counterpart for it.

   After the formation of the Earth about 4.5 trillion years ago, there should have been atmosphere with hydrogen H_2, methane CH_4, ammonia NH_3 and of course water H_2O but no oxygen O_2 since its presence would led to the oxidation (combustion) of hydrocarbons. The Miller-Urey experiment (see) showed that basic amino acids could have formed in this way: for the TGD view see [L6, L8].

2. There is also a second constraint. Nitrogen atoms are essential for life. The binding energy of N_2 is a huge, about 9 eV. How to break down N_2 to free nitrogen to get for instance NH_3? Very early on, lightnings produced N atoms: the entire Earth acted like a volcano. Later, this wasn't enough. Bacteria invented an enzyme called nitrogenase that catalyzed the breakdown of N_2.

3. Everything was going well until the "Great Oxygenation Event" happened and the water at the surface of the Earth (oceans if they did exist) was oxygenated. Cyanobacteria living in the oceans invented photosynthesis that produces O_2 as a byproduct and the reducing environment became oxidizing. This was a huge catastrophe and almost killed the existing bacteria to extinction because oxygen is a poison for nitrogenase. Nitrogenase had to be protected and bacteria invented many ways to do this and life in the oceans could continue. Much later, bacteria produced nitrogen for the entire ecosystem. Plants specialized in photosynthesis and bacteria are essential for them. Animals just had to eat plants or other animals from the ready table. A food chain was born bacteria-plants-animals was born.

   To sum up, oxidation as necessary condition for photosynthesis but oxygen is the enemy of nitrogenase need to generated compounds of nitrogen and hydrogen as essential components of proteins and DNA/RNA. Life is dangerous.

1.2 Cambrian Expolosion as a starting point

The TGD view of the evolution of life has developed gradually by twists and turns from a TGD based explanation of Cambrian Explosion (CE) .5 billion years ago, which is a mystery of the recent view of biological evolution [I4]. In CE highly evolved multicellulars emerged and it is very difficult to understand the scarcity of fossiles before CE.

1. For almost two decades ago [K2] I asked whether life could hve evolved in underground oceans and bursted to the surface of Earth as the radius of Earth increases in a geologically short time interval by factor 2 and have developed this proposal during years [L13, L12]. This idea has led to an explanation for an impressive number of anomalies.

   The proposed interpretation was that these kinds of sudden increases of the size could be the TGD counterpart for a smooth cosmic expansion predicted by General Relativity.

2. In this article a different interpretation is discussed and leads to a revised vision about geological and biological evolution of the Earth. It is based on the TGD inspired proposal that Moon was created as a layer of the Earth exploded and gravitationally condensed to form the Moon [L19]. The proposal explains why Moon and Earth have same composition: in Theia model there is not reason for this.

3. In the first version of the model I did not realize that the direct generalization of the Theia does not take into account the resulting recoil effect. This recoil would have induced a contraction of the Earth, modellable as an elastic ball, reducing its radius by a factor 1/2 as follows from conservation of the total angular momentum. The rotation velocoty in the beginning was 4 times higher than now and was not affected in the recoile. During the expansion period the radius increased by factor two and at this time the angular momentum was conserved and the length of the day increased by factor 4 to 24 hours.

1.2.1 Questions related to water

The TGD inspired view started to evolve from a model for Cambrian Explosion [K2] and eventually led to several questions.

1. How did underground water reservoirs and perhaps even oceans emerge? I have considered various models based on the new quantum physics predicted by TGD. For instance, could the dark protons at the magnetic body have experienced reverse Pollack effect and dropped down to the magma and combine with O_2 to form water molecules. These water molecules could also have formed exclusion zones (EZs) with part of the protons at the magnetic body.

2. Did only a part of the underground water formed in the beginning of the Earth's geological evolution burst to the surface. Did the underground water form oceans or at least large water reservoirs where multicellular life could have evolved. The emergence of water to the Earth is only a small part of the narrative about the evolution of life on Earth and in the following I try to build a TGD counterpart of the standard narrative based on what anyone can learn by using language models such as Google Gemini.

1.2.2 Did Earth make its water by itself?

The original stimulus for writing this article came from a popular Quantamagazine article "How did Earth get its oceans?" (see this).

The models for the generation of water on Earth have problems. An old theory is that comets brought the water. The D/H ratio for them is however different from that for the water on Earth. One explanation could be that they have travelled through D rich clouds and this has changed the ratio at their surface. Second theory is that asteroids between Earth and Mars have brought the water. Now the D/H ratio is acceptable but the mixtures of noble gases are different from those for Earth.

The proposal of the article [E1] by Horn et al is that Earth made its water itself. It is motivated partially by the observation that exoplanets known as sub-Neptunes very near their stars can have atmospheres rich in water. This is plausible. There is a lot of O_2 in the magna and H_2 in the atmosphere at high pressure. Could these planets make the water by themselves? This proposal has been tested in a laboratory and the amount of water produced was about 1,000 times higher than predicted.

The proposal of is that H_2 molecules present in the atmosphere of the Earth at huge pressure penetrated underground to the molten magma and this led to the formation of water molecules. The pressure in the range 27-100 atmospheres allows water phase in the temperature about 2,300 K. Did the water burst to the surface and lead to the formation of oceans. Were underground water reservoirs, even oceans, formed?

This period would not have lasted for long. Cooling and reduction of the pressure was necessary for the formation of basic biomolecules including CH_4, H_2O and ammonia NH_3. Soon the Earth lost its H_2 atmosphere so that the time window for the formation of basic molecules of life was rather narrow.

1.3 Basic ideas of quantum geology and biology

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1. The contraction of the Earth radius by factor 1/2 implies the increase of the density by factor 8. In the framework of standard model physics implies a huge increase of pressure and temperature and life could not have evolved in underground water reservoirs if they could be even present. Large scale quantum coherence could however change the situation.

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I have included a long Appendix summarizing the basic facts about the geological and biological evolution. The reader is encouraged to personally check whether the proposed view is consistent with them. New objections are always well-come.

2 Expanding Earth hypothesis as a key to the understanding the geological and biological evolution of the Earth

How does this vision relate to the TGD view of Cambrian Explosion (CE) [K2] [L13, L29] based on Expanding Earth hypothesis.

1. Multicellular life would have evolved in underground oceans shielded from cosmic rays and meteor bombardment and bursted to the surface of the Earth in CE [L34]. Earth radius would have increased by a factor 2 in CE. If oceans were present from the beginning also at the surface, one could understand why the life survived the period of Iceball Earth if this period was really present. The tectonic plates would have emerged in CE as the rapid expansion would have bursted the water to the surface.

2. The first question is whether the oceans present also at the surface of Earth all the time or were they formed, or rather reformed, in CE, which is believed to be preceded by the so called Snowball Earth. This is the standard view and the very early history of life is consistent the presence of oceans. In particular, the occurrence of Great Oxygenation event about 2.4-2.0 Gy ago is supported by the red layers, which have been assigned with ancient ocean bottom. The assumption about the presence of oceans might however too strong. Also Mars, with radius equal to one half of the Earth radius as also Earth before CE in TGD view, is also red and does not have oceans (but could of course have had them in distant past).

3. An alternative possibility is suggested by the situation in Mars, where there is no plate tectonics and there is water at the surface in small amounts but oceans are absent. The radius of Mars is one half of that for the Earth, that is the radius of the Earth before CE if the TGD view is correct. This suggests that before CE the situation at the Earth was like in Mars and that the oceans at the Earth were formed in CE. For this option there would not have been Snowball Earth. Even it surface oceans were present there is no reason why the multicellular life could not have evolved underground, shielded from cosmic rays and meteoric bombardment and in oxygenated water making photosynthesis and evolution of multicellulars possible.

2.1 Problems to be solved

2.1.1 How did the underground water reservoirs emerge?

The first question is how the water emerged as underground water reservoirs. The view discussed in [L29] involves dark phases of ordinary matter at the magnetic body, at least dark hydrogen ions and water molecules of magma or crust. Large scale quantum coherence is involved and one can ask whether this mechanism might be more effective and explain why the amount of water produced in the experiments of [E1] was 1000 times larger than expected.

This is not the only imaginable option and it need not generate underground water reservoirs. The proposal for quartz life [L20], motivated by the notion of conscious computer, inspires an alternative mechanism for generation of the underground water in the crust of the Earth. Water reservoirs could be identified as fractures of the crust. The simplest mechanism would be as follows.

1. In presence of H_2, the SiO_2 crystal (actually a lattice having SiO_4^{4-} as basic units) can form SiOH gel at its surface. The reaction SiOH+SiOH = Si-O-Si + H_2O occurs spontaneously in the temperature range: 150°C to 400°C. SiOH is in gel phase and if hydrophilic it could act as a catalyst for the Pollack effect which could could generate dark protons at the gravitational magnetic body. This could give one possible realization of what might be called quartz life.

2. The adjacent surface SiOH groups begin to react with each other, releasing trapped and bonded water vapor into the air. The reaction is $\equiv$ Si-OH+ $\equiv$ Si-OH $\stackrel{\Delta}{\rightarrow} \equiv$ Si-O-Si $\equiv$ $+H_2O(g)$. Above 800°C virtually all surface SiOH groups are destroyed, leaving behind a completely dry, fused siloxane (Si-O-Si) glass framework. The process can be regarded as dehydration. If the flowing hydrogen gas is passed over the silica at even higher temperatures (above 1000 °C), the H_2 will aggressively strip oxygen from the newly formed Si-O-Si bonds, producing even more water vapor and generating silicon monoxide (SiO) gas.

3. Also the possibility that water is present from the beginning can be considered. In this case SiOH would be formed at the boundary of water and SiO_2. Also in this case SiOH acts would act as a catalyst for the Pollack effect. This would suggest the possibility of water containing regions bounded by quartz crystals that I have considered already earlier [L29].

These regions need not correspond to fractures of the crust. These regions of microscopic size could fuse to larger connected lattice-like structures.

The TGD based model for Allais anomaly [L32] led to the proposal that the so called warping of the space-time space-time surfaces distinguishing general relativity andTGD, leads to a decomposition of spacetime surface to regions characterized by reduced value $c_{\#}$ of light velocity. Interestingly, in electrodynamics the relative dielectric constant equals $\sqrt{c}/c_{\#}$. The 3-D surfaces separating these regions would be quantum critical and could serve as seats for the evolution of life. One can ask whether the water containing regions could be bounded by 3-D surfaces separating them from the crust consisting mainly of SiO_2 crystals.

4. SiOH could be created at the surface of the fracture by mechanical stress. When crystalline or amorphous SiO_2 is violently grinded, shattered, or ball-milled, the physical shearing forces tear the internal covalent bonds apart. This creates highly unstable, open-shell "dangling bonds" specifically, silicon radicals ($\equiv$ Si$^\bullet$) and non-bridging oxygen radicals ($\equiv$ Si-O$^\bullet$). If this crushing occurs inside a sealed chamber pressurized with pure hydrogen gas, these freshly exposed, naked radicals instantly snap up the ambient H_2 to stabilize themselves, forming surface SiOH and SiH groups at room temperature. The presence of H_2 is however needed. This kind of mechanism might work in the violent conditions of the young Earth. One can ask whether the 4:th phase of water created in Pollack effect in negatively charged exclusion zones (EZs) is stable. Metabolic energy feed could stabilize it.

2.1.2 Was the development of multicellular photosynthesizing life really possible in underground reservoirs?

The development of multicellular life poses very strong, almost impossible looking, conditions on the underground water reservoirs.

1. The metabolism based on photosynthesis requires radiation as an energy source. I have considered two options. Dark photons from the Sun arrive along monopole flux tubes without dissipation to the reservoir or from the Earth's core.

2. There are strict bounds on pressure. The Miller-Urey pathway requires that pressure is below 5 atmospheres. If CO_2 dominates the atmosphere the bound is not so strong. It however seems that basic biomolecules most naturally emerge at the surface of Earth and later end down to the water reservoirs. The formation of water by the mechanism of [E1] could create the water reservoirs and only part of the water would end up to the surface of Earth.

   The pressure decreases with an average rate $dp/dh \sim .3bar/m$ in the land crust and with a typical rate of $dp/dh \sim .1bar/m$ in the oceanic crust. Note however that deep oceanic pressures can be as high as 1,100 atmospheres so that the organisms living in these circumstances must have developed means to survive this pressure. Below land crust, the pressure increases to 5 bar at the depth of 17 m so that the Miller-Urey process is plausible only at the surface.

3. The development of multicellular photosynthesizing life, according to the standard view, poses even more stringent conditions on temperature inside water reservoirs. Temperature increases with an average rate $dT/dh \sim 2.5 - 3.0$ °C/m in the crust. The rate can however vary in rather wide bounds.

   Multicellular life involving photosynthesis utilixing oxygen is possible only at temperatures below 100 °C. At the ocean bottom the temperature is near zero and would increase to 100 °C at depth of 40-30 m.

   Traditional photosynthesis using sunlight is impossible at the bottom of deep ocean because sunlight completely disappears below 200 meters. There is however a mind-blowing exception: a specialized bacterium can perform sun-free photosynthesis at the absolute bottom of the ocean by harvesting the dim, thermal glow of hydrothermal vents. The temperature in deep hydrothermal vents can exceed 150 °C and even 400 °C. The life in the hydrothermal vents utilizes chemical energy and does not involve photosynthesis in general.

The condition that photosynthesis is possible is very stringent. The TGD vision would suggest that either dark photons from the Sun or from the Earth interior arriving along the monopole flux

tubes or photons of the thermal radiation could have made photosynthesis possible in underground water reservoirs. In key aspects, the life that possibly bursted to the surface in CE should have been rather similar to the recent life in order to survive the transition. Therefore the circumstances inside the water reservoirs should have been rather similar to those in the water at the surface of Earth nowadays. Could life have invented mechanisms to keep the temperature and pressure in the bounds prevailing at the surface of the Earth so that they would have survived the transition?

1. The problem with temperature

In the case of temperature problems, one can consider two alternative solutions, which both involve the Pollack effect.

1. The purely quantal solution to the temperature problem is large scale quantum coherence. The basic quantum objects have large size and mass. Therefore the thermal fluctuations would have been reduced and temperature measuring their importance would have been low. The concrete realization would have been in terms of Pollack phases of the matter inside the mantle. The protons and possibly alkali ions neutralizing the silicate would have been dark and located at the gravitational magnetic body. The temperature could have had the values prevailing inside organisms nowadays. Note that the low temperature of Si_4O^{4-} allows also ordinary phases of matter inside water reservoirs where the multicellular life would have evolved. One especially interesting variant of silicate are clays which has been proposed to be a predecessor of organic life [I2] [K3].

2. Could the Pollack effect be essential for the solution of the temperature problem? Pollack effect generates negatively charged exclusion zones (EZs) which, or at least the associated magnetic bodies, seem to have a reverse arrow of geometric time. The control by the magnetic body could induce an effective arrow of time at the level of the ordinary matter. For instance, EZs throw out impurities and can have a temperature lower than that of the environment. Ordinary cells and DNA also have permanent negative charge and could correspond to EZs.

   Could the water reservoirs correspond to EZs and be able to keep their temperature near the physiological temperature? This looks implausible. The only reasonable variant of ZEO is that EZs existed only during the geologically short quantum phase transition periods ("big" state function reductions, BSFRs) in which the radii of gravitational harmonic oscillator states reduced dramatically.

2. The problem with high density and pressure

The increase of the density by factor 8 before the CE occurring during the compression of, say water, creates extremely high pressure about 2 TPa. Normal quartz has density of 2.65 g/cm^3 and highest densities are about 4.3 g/cm^3. In the standard physics framework 8-fold density and corresponding pressure do not look plausible and at these densities and pressures prevailing inside the Earth, it is very difficult to think how the evolution of ordinary life could have evolved.

It seems that the basic solution is purely quantal: the matter in the compressed phase inside the Earth would have been in Polack phase with the positive ions neutralizing the SiO_4O^{4-} lattice at the gravitational magnetic body.

1. Pressure depends strongly on the number of the thermalized translational degrees of freedom. The generation of entanglement made possible by quantum coherence in macroscopic scales can reduce this number dramatically, which suggests that the dark phases of matter with large h_{eff}, even water, could have high densities. There pressures in the underground reservoirs and also outside them could have been normal and there would be no need for shielding. For instance, the silica inside the mantle could consist of large macroscopically quantum coherent regions with an 8-fold density and with very low pressure and temperature. This would allow quantum coherence, not only near the surface of the Earth, but also in longer scales, at least down to the core with radius roughly $.546R_E$. Note that for Mars the radius of the core is $.496R_M$, very nearly equal to one half of the radius.

2. These quantum coherent regions could correspond to the EZs created by the Pollack effect. Protons added to $-O^-$ ions generate hydroxyl groups -OH. Pollack effect could transfer the

protons to the gravitational magnetic body of the Earth. One can think that the explosion increasing the radius by factor meant a reverse Pollack effect bringing the dark protons back to the silicate lattice. Therefore the compression followed by expansion could involve a transition between ordinary and dark variants of the silicate lattice. The Pollack effect gives rise to large-scale quantum coherence but does not yet explain the reduction of atomic distances by factor 1/2.

3. Could one imagine the existence of some kind of honeycomb structure with walls formed from silica? Here the completely unique icosa-hedral tessellation (ITT) of hyperbolic 3-space proposed to give rise to the genetic code comes to mind. The proposal is that ITT has a counterpart hydrogen bonded supercluster in water [L33]. ITT has icosahedra and tetrahedra as basic building blocks and dodecahedra give rise to empty volumes whose counteraparts at the level of water would contain water. In CE the radius of the Earth increased in a geologically short time interval so that the lattice structure as a rigid structure would have been destroyed. This process is analogous to hatching in which the chicken emerges from the hen egg (note that the hen egg is a single cell and the egg shell consists of carbonate $CaCO_3$). Could this correspond to the phase transition in which dark silica became ordinary silica as dark ions became ordinary.

One can adopt a more conservative attitude and ask whether ordinary silicate could have allowed the existence of underground EZs in the recent mantle?

1. Diatoms are single-celled algae (phytoplankton) having a cell wall made of silica SiO_2. There exist no cell colonies surrounded by silica walls although the individual cells of the colory can be surrounded by silica walls. Could the possible recently existing underground organisms utilize the surrounding silica as a shield against the pressure of the mantle at higher depths? The pressure inside underground Pollack water reservoirs identified as EZs containing living matter should be rather low. Therefore the difference between the internal pressure of silica and pressure of the reservoirs is large and would compress it.

2. Could a lattice-like honeycomb structure for silicate possible down to depths 50-250 km (the depth depends on whether a mid-ocean ridge, a subduction zone or a mantle hotspot is in question) be stable against collapse: the silicate would be like a porous material. At large depths the liquid like magma does not allow this kind of reservoirs.

For both options, the increase of the pressure during the contraction phase would have forced the emergence of life by forcing quantum coherence of the mantle and generation of the dark phase of biologically important ions. The recoil effect generated by the creation of the Moon would have been the first step in the evolution of biological life.

2.1.3 The problem of CE vision with angular momentum conservation

The TGD view of CE has a problem with angular momentum.

1. Angular momentum conservation predicts that the in CE the rotation velocity of the Earth was slowed down by factor four due to the increase of the radius by factor 2. Therefore the day lasted 6 hours rather than 24 hours. Therefore the rotation would have been considerably faster than it is today, so the day only lasted about six hours.

2. Standard approach to the formation of the Moon suggests an alternative explanation. The prevailing theory has been that the Moon was formed as a planet with mass of order Mars mass, christened Theia, collided with the Earth. The total angular momentum of Moon-Earth system was conserved so that the rotation velocity of the Earth was gradually slowed down. This is skater effect in which reduction of moment of inertia increases rotation velocity. The estimate for the length of the day is 4-6 hours at the moment of the collision! A simple estimate gives 5 hours. The two views make the same prediction but for the TGD view the angular momentum of the Earth is conserved but for the standard view this is not the case. Which explanation is correct, are both wrong, can both be correct or should one fuse them to a better explanation?

I have considered as one possible solution to this problem in [L29] in terms of zero energy ontology (ZEO).

1. The increase in radius for the Earth and the deceleration of rotation due to the gradual increase in the angular momentum of the Moon in a continuous way provides a classical description.

2. I however noticed a mistake in my interpretation of the effect of the Moon's formation. I had started from the hypothesis that the moon was created by Theia's collision with the Earth and naively generalized to a model where the Earth throws out its shell. The rotation rate would have decreased by a factor of 1/4. The model for the collision with the Theia does not however apply now.

   The ejection of the mass shell produces a recoil that compresses the radius of the Earth. The situation resembles a supernova and also the formation of a black hole and probably the mathematics has the same features as in the case of a supernova. The radius decreases by factor 1/2 and starts to increase again. Could this be due to the angular momentum conservation for the Moon-Earth system. Could the increase by a factor of 2 correspond to what happens in CE. The radius would increase by a factor of 2.

2.2 The new view of the formation of the Moon

How the situation should be handled.

1. The conservation of energy and radial momentum must be used. Here, the analogy is the curvature of the radius R dynamics of cosmology. Except that now the contraction occurs first. As the Moon separates, it gains angular momentum, and the conservation of angular momentum reduces the Earth's angular momentum. Does the decrease in Earth's radius primarily explain the decrease in angular momentum? In this case, the radius should decrease by a factor of 1/2. CE would restore the radius to its original value.

2. The crust of mass flies out. A recoil occurs and the Earth compresses. The decrease in radius reduces the Earth's angular momentum. Could it compensate for the increase in total angular momentum produced by the Moon by CE? The correct result would be obtained if the radius decreased by a factor of half and after CE it increased by about a factor of 2. Assuming this, the rotational speed does not change during compression. The Moon would dominate the dynamics of the radius decrease.

3. The recent increase of Moon distance is about 3.8 cm per year and has incresed 1.54×10^7 m after CE: roughly 2 twice the radius of Earth. The distance of the Moon varies in the range 56-64 Earth radii. On this time scale, CE would be a fast process. The occurrence of CE would restore the radius to its original value and the rotation rate would decrease if the coupling to the Moon could be neglected. The original proposal that CE corresponds to cosmic expansion occurring in bursts is not consistent with the new interpretation.

2.3 The classical view of the pre-CE dynamics as the contraction of the Earth radius

By the conservation of the total angular momentum, the dynamics of the radius decrease would be completely determined by the growth of the Moon's radius. However, there would be a lower limit and it would correspond to half the Earth's radius. It is determined partly by the increase in pressure and partly by elasticity.

The natural idea is to model Earth as an elastic magma ball and a model as a classical harmonic oscillator is the lowest approximation. Elasticity would imply that compression cannot continue indefinitely. An elastic force would arise and one can see the time contraction and expansion phases as a bounce. It turns out that this view predicts quite too short a time scale for the bounce whose time scale is controlled by the angular momentum conservation for the Moon-Earth system.

2.3.1 The model of the Earth as an elastic ball cannot describe the contraction phase

The first guess is that the recoil induces radial oscillation taking the radius to $R_E/2$. It turns out that the oscillation period is quite to short as compared to the duration of the period with radius $R_E/2$ measured using 4 Gy as a natural unit.

1. The maximal decrease of the radius ΔR would be

$$\Delta R_m = v\sqrt{\frac{M_{layer}}{k}} \ .$$

v is the initial radial compression velocity. It is related by momentum conservation to the velocity of Moon v_M as

$$v = \frac{M_M}{M_E - M_M} v_M \simeq .01 v_M \ .$$

v_M can be parametrized in terms of the escape velocity

$$\frac{v_0}{c} = \sqrt{r_s/R_E} \simeq .4 \times 10^{4-}$$

as $v_M = x v_0$ so that one can write

$$v = \frac{M_M}{M_E - M_M} x v_0 \simeq .4 \times 10^{-6} x \mathrm{m/s} \ .$$

M_{layer} is the mass of the layer of the Earth involved with the deformation. For a layer of thickness d at the surface one has $M_{layer} = y_{layer} M_E$, $y_{layer} = (1 - (R_{E_-}/R_E)^3)$, where R_{E_-} is the lower radius of the layer.

2. $\Delta R = \frac{R_E}{2}$ gives the condition

$$\frac{M_M}{M_E} x v_0 \sqrt{\frac{M_{layer}}{k}} \equiv x \frac{M_M}{M_E} \frac{v_0}{c} (\frac{c}{\omega}) = \frac{R_E}{2} \ .$$

The expression of ω given below shows that the abobe condition does not depend on the value of x at all. The value of x is completely fixed by the condition for the initial velocity $v = x v_0$ givs a condition relating ω and x:

$$\omega = x \frac{M_M}{M_E} \sqrt{\frac{r_s}{R_E}} (\frac{c}{R_E}) \simeq x \times .5 \times 10^{-6} (\frac{c}{R_E}) = 2.36 \times 10^{-5} x \ \mathrm{Hz} \ .$$

For $x = 1$, this corresponds to a period $T = 1/\omega = 11.8$ hours which is almost the half period of the Earth's rotation. A 1 per cent smaller value of x would give 12 hours. Note that the value of ω is proportional to x. It will be found that for $x < 100$ the values of bulk moduli associated with the structures of Earth can be understood. $x = 100$ would give period of 7.1 minutes. $x = 12$ would give 1 hour period.

From this it is clear that the contraction and expansion phases cannot be understood in terms of the oscillator model: the time scale for them is 4 Gy.

3. For k the formula $k = m\omega^2$ gives the estimate

$$k = y_{layer} x^2 \times k_0 \ ,$$
$$k_0 = \frac{M_M}{M_E}^2 \frac{r_s}{R_E} \frac{c}{R_E}^2 M_E \simeq 2.36^2 \times 10^{-10} M_E/\mathrm{s}^{-2} = \sim 3.1 \times 10^{15} \ \mathrm{kgs}^{-2} \ .$$

Elastic constant k, having the dimension $\mathrm{kg/s}^2$, relates to the bulk modulus K with dimension $\mathrm{kg/ms}^2$ for the region involved with the reduction of the radius. If the radius entire Earth is involved the bulk modulus $K \sim 130$ GPa. The bulk modulus of the entire planet is estimate to be 130 GPa.

4. An estimate for the bulk modulus in terms of he elastic modulus k for a effectively 2-dimensional layer of Earth with thickness d is as

$$K = \frac{k}{d} \ .$$

This gives

$$K = y_{layer} x^2 \times K_0 \ ,$$
$$K_0 = \frac{M_M}{M_e}^2 \frac{r_s}{R_E} \frac{c}{R_E}^2 \frac{M_E}{R_E} \simeq .5 \times 10^9 \ \text{ kg m s}^{-2} = .5\text{GPa} \ .$$

GPa is the natural unit for the values of bulk modulus in Earth length scales. The range of K/GPa is $[10-50]$ for the crust, $[35, 660]$ for the upper mantle, $[660, 2, 890]$ for the lower mantle $[2, 890, 5, 150]$ in the outer core. The value $x = 100$ is consistent these values of K.

5. Some values for the length scales in order. The radius of the core is $.55R_E$, the radius of inner core is $.19R_E$. Outer core thickness is $.36R_E$, where $R_E = 6,370$ km. The thicknesness of the inner mantle is $d \sim 10^{-1}R_E$.

The mass $M_M \simeq .013M_E$ of the Moon corresponds to a layer of thickness $\Delta R/R_E \simeq (1/3) \times (M_M/M_E) simeq.004$. This gives $\Delta R \leq .5 \times 10^{-3} R_E \simeq 25$ m which is a typical value for the crust of the Earth. Therefore the creation of the Moon would throw out a layer identifiable as a proto crust.

2.3.2 Who was the master and who was the slave?

From the estimate of $T = 11.8$ hours for the oscillation period, one can conclude that this model cannot describe the reduction of the radius lasting about 4 billion years. The oscillations in question are however very interesting as such. A more realistic description would be as a change of the equilibrium position of the harmonic oscillator forced by the angular momentum conservation for the Moon. Could the Moon be regarded as the master and Earth the slave of this dynamic? Or was the angular momentum conservation the real master.

This suggests that the radius corresponding to the equilibrium position decreases to $R_E/2$ adiabatically. The rate for the decrease of R_E is dictated by angular momentum conservation for the Earth-Moon system. In this dynamic, the Moon serves as the master and the Earth as the slave.

In fact the quantum phase transition reducing the atomic radius by factor 1/2 would have been the real master of the dynamics. It forced the reduction of the radius of Earth by 1/2 and liberated huge gravitational binding energy throwing out the layer condensing to form the Moon. The liberated atomic binding energy provided metabolic energy for phase transitions creating the phases with h_{em} and h_{gr}.

2.4 A model for the transition scaling the distance between atoms by factor 1/2

The challenge is to construct a model for the phase transition, which scales the distance between atoms by factor 1/2 and increases the density by factor 8. It seems that quantum coherence is needed to reduce the number of translational degrees of freedom and the Pollack effect could help in this. It does not however allow us to understand the mechanism giving rise to reduction of the scale by factor 1/2 and here the p-adic length scale hypothesis suggests a rather concrete model.

2.4.1 Silicates and Pollack effect for silicates

It seems that the Pollack effect is possible only for the silicates containing -OH groups. The reason is that these ions have ionic rather valence bonds to the orthosilicate anions. Pollack effect is not possible for quartz for which all oxygens of neighboring units form valence pairs.

There exists a huge number of silicates. The basic unit is the orthosilicate anion SiO_4^{-4}. Ion bonding with metal ions such as Mg^{2+}, Fe^{2+}, Fe^{3+} or Ca^{2+} or oxygen atom sharing stabilizes. Aluminum Al^{3+} can substitute for Si within the tetrahedron. Because aluminum has a +3 charge

compared to silicon's +4, this substitution creates a localized excess negative charge, which attracts additional positive cations.

The following classification is based on the oxygen atoms shared by neighboring units.

1. Nesosilicates have separate SiO_4^{-4} ions, which are like islands in a sea formed by neutralizing Mg^{2+}, Fe^{2+} and other ions. These do not have valence bonds to oxygen ions, but the bonds are ionic bonds. Nesosilicates, Island silicates. Olivine is a basic example.

2. Sorosilicates (double silicates) consist of two such layers so that there is an O-O bond between the tetrahedra of the layers and the other 3 charges are neutralized by the sea. Now we can also think of local neutralization with H^+, which gives the Pollack option.

3. Inosilicates (chain silicates). The basic units share 2 or 3 oxygen atoms. The result is chains or double chains (Pyrosense, Amphiboles).

4. In sheet silicates, the oxygen atoms have 3 O-O bonds to their neighbors. The fourth O^- is neutralized. It could also be neutralized by H^+. K^+, Na^+. These could form Pollack silicate if these ions can give the gravitational magnetic body. The findings of Blackman suggest that this is possible. Mica (fool's Gold) and talc serve as examples of sheet silicates.

5. The simplest silicate is a tectosilicate, which has only O-O bonds. This corresponds to quartz. Tetrahedron is the basic building block and no cations are needed. Quartz and feldspar served as examples.

6. Also sandwich-like structures involving tetrahedron layers having an octahedron layer between them. The octahedron layer can consist of ions like Mg^{2+} and in very high pressures also Si octahedra with 6 oxygen ions are possible. Clays provide a key example of these structures and involve the octahedral sheet Aluminum centered sheets with -OH groups at the 6 vertices.

What could the correct identication of the Pollack silicate be?

1. One could think that in silicates other than quartz, O^- are replaced by OH in some places. Hydrogen (H^+ can be regularly incorporated into the structure of hydrated silicates (such as clays and serpentine) to balance the remaining charges of unshared oxygen ions. The transfer of (H^+ to the gravitational magnetic body would give rise to Pollack effect. O^- and OH would define a qubit.

2. Clays (see this) have been proposed by Cairns-Smith (see `http://tinyurl.com/y8wfyha4` [I2] as a candidate for predecessors of life [K3]. The reason is that silicon, which is the building brick of clay minerals, has a chemistry similar to that of carbon and allows a very rich repertoire of polymers. The division of clay layer to two layers growing after that to the original size could be seen as a very simple replication mechanism. The -OH groups associated with the octahedral vertices make Pollack effect possible. This could make octahedral layer a catalyst: clays are indeed known to act as catalysts.

3. Metabolic energy storage is an essential element of life and clays have the geometric structure of a battery and an attractive idea is that could develop electric potential between the layers and act as what might be called a Pollack battery. I have developed a rather detailed quantum model of Pollack battery in [L35], which also explains the mysterious Biefel-Brown effect [L17]. The charge separation occurs basically between battery and magnetic body and the electric field distinguishes between the layers. The numbers of dark protons transferred to the magnetic body from the -OH groups are different at the two layers so that one can speak of cathode and anode. The middle layer would catalyze the Pollack effect. This generates an electric field. Could this kind of structure have served as a primordial cell with water inside the sandwich playing the role of the cell interior.

2.4.2 A quantum model for the scaling of distances between atoms by factor 1/2 or its power

The geological evolution of the Earth is proposed to involve a downwards scaling of the Earth radius by factor 1/2 and a compensating expansion. Standard physics does not provide any obvious physical model of how atomic distances could scale down by a factor of 1/2 . The ultradence phase of atomic matter reported by Prof. Leif Holmlid [C1] suggests also higher powers of 1/2.

TGD suggests that the p-adic length scale hypothesis could serve as a quantitative guide line.

1. p-Adic length-scale hypothesis predicts p-adic length scales $p \simeq 2^k$, where prime values of k are favored. One can list the possible p-adic scales satisfying this criterion in condensed matter scales and there are fascinating connections between number theory and physics.

2. Primes $k = 137$ and $k = 139$ form a twin prime pair and their p-adic length scales differ by factor 2. They correspond to p-adic length scales .781 $\AA$ and 1.56 $\AA$. The typical values of the radii of condensed matter atoms are in the range 1.45-1.95 $\AA$, which suggests the value $k = 139$ for the atoms. Note that $k = 137$ corresponds to the inverse of the fine structures constant: a kind of cosmic joke?

3. In the length scale range between cell membrane thickness and the size of cell nucleus there are 4 Gaussian Mersennes corresponding to $k = 151, 157, 164, 167$. Also the p-adic length scales $k = 149$ and $k = 151$ assignable to the lipid layer of neuronal membrane and the membrane itself for a twin pair. One can wonder whether these p-adic length scales somehow emerged in the transition considered.

For 3-dimensional structures, the density increases by a factor of 2^3 as the Earth's radius scales by a factor of 1/2. Also more general scalings with powers $1/2^{k_1}$, $k_1 = 1, 2...$, are in principle possible and the claims of Prof. Leif Holmlid [C1] related to "cold fusion" suggests also higher powers of 1/2.

Also structures with smaller dimensions $d = 1$ or 2, that is string-like objects and membrane-like objects, can be considered. For d-dimensional structures the density of atoms in the structure increases by a factor 2^d in the scaling by 1/2.

The basic unit corresponds to an atom, the size of which can be scaled p-adically by a negative power of two.

1. If favored p-adic length scales are characterized by primes values of k, one can ask whether the transition $k = 139 \to k = 137$ induced this transition? The scaling of density by factor 1/2 should reduce the size of atoms by factor 1/2 and icrease density by factor 8.

   There is actually empirical evidence for this kind of phase transitions: Mills has induced the notion of hydrino atom [D2] and I have discussed his claimns from the TGD point of view in [L3].

2. The transition $k = 139 \to 137$ could also correspond to the transition $h_{eff} \to h_{eff}/2$ increasing the value of $\alpha = e^2/4\pi\hbar_{eff}$ by factor 4 and increasing the scale of binding energies by this factor. This would liberate energy. It would reduce the Bohr radius $a_0 = \hbar_{eff}/2\alpha$ by 1/2.

The density of repulsive Coulomb energy between atomic nuclei and electrons should be reduced. How to achieve this?

1. In many-sheeted space-time, the change of h_{eff} can depend on the space-time sheet. Could the value of h_{eff} increase at the space-time sheets determining carrying the repulsive Coulomb energy so that the energy decreases or, at least, remains as such.

2. Due to the increased quantum coherence length, the structure would consist of overlapping quantum coherent units L formed from several atoms just like in superconductivity or superfluidity. In the recent case, it would reduce pressure and temperature since the number of translational degrees of freedom is reduced. The larger the size L is, the smaller is the electrostatic energy, which is inversely proportional to the size of the quantum coherent unit L. $E_C \propto 1/L$ is the natural dimensional guess for the Coulomb energy. The reason is that the ions involved can have larger distances reducing the Coulomb energy.

3. Stability requires that the increase in the size of the quantum coherent unit at least compensates for the increase of the electrostatic energy due to the increase of the density of the basic structures. In the minimal situation, the electrostatic energy should remain approximately the same in the allowed scalings. It could also decrease. When the density for a d-dimensional structure increases by a factor of $2^{d\Delta k}$, the electrostatic should energy decrease correspondingly so that the scale L should increase at least by a compensating factor of $2^{d\Delta k}$.

This suggests a connection to the p-adic length scale hypothesis giving a criterion which p-adic scalings as quantum transitions are possible.

1. Suppose $p \simeq 2^k$, k prime. By above argument the transition $k = 139 \to k = 137$ is plausible. For an atom, with $k = 139$ applies and the p-adic scale is about 1.56 $\AA$ ($L(139) \simeq L(151)/64 \simeq 1.56$ $\AA$) Actually, at least fail to understand well why the size of atoms doesn't seem to depend much on the atomic weight. The classical Bohr model of the atom gives the maximum radii of the electron orbits, which depend quite strongly on the atom.

2. Assume that the allowed p-adic length scalings $2^{-\Delta k}$ of atoms correspond to p-adic lengths $k = 137 + 2d\Delta k$ for quantum coherence regions of d-imensional structure such that k is prime. This would guarantee that the Coulomb energy does not change appreciably. One would have fractality and scale invariance. Of course, Δk could be larger than the minimal value so that the repulsive Coulomb energy would decrease.

3. An attractive interpretation is that the liberated atomic binding energy serves as metabolic energy whose basic function in TGD inspired biology is to increase the value of h_{eff} and thus increase the scale of quantum coherence. This allows the emergence of all p-adically relevant p-adic length scales at once in the transition $k = 139 \to 137$.

4. Was the contraction of the Earth implied by the creation of the Moon or did the contraction liberate the energy throwing the Moon out of the system? The contraction of the Earth liberated gravitational binding energy and a rough estimate for the ratio of the gravitational binding energy of the Earth Moon system to the reduction of the Earth's gravitational binding energy is about 1/25. Perhaps one could say that the phase decreasing the density by factor 1/8 led to the liberation of the gravitational energy throwing out a surface layer.

The assumption that k is prime is very strong and leads to strong predictions for possible p-adic phase transitions. One can consider two options for the first prime k_0 corresponding to $k_0 = 137$ or $k_0 = 139$. $k = k_0 + \Delta k = 139 + 2dn$ must be a prime number, $d = 3, 2$ or 1.

1. $d = 3$-dimensional case predicts $\Delta k = 6n$ as the density increases by a factor of 2^n and scaling by $1/2^n$ occurs. Of course, also the scalings by 1/2 can induce $\Delta k = 6n$: the quantum coherence would be only longer than necessary.

   (a) The series associated with $k = 139$ is $k = 139 \to 151 \to 157 \to 163 \to 169$. The steps after the first one correspond to the scale hierarchy associated with the cell. The first 3 primes label Gaussian Mersennes as also is $k = 167$ defining the size scale 2.5 μm of the cell nucleus. These primes are a number-theoretic miracle and are related to the structures of DNA. $k = 151$ corresponds to the thickness of the cell membrane. $k = 169$ is a p-adic length scale associated with the strength of the magnetic field strength $B_{end} = .2$ Gauss.

   (b) The series associated with $k = 137$ is: $k = 137 \to 149 \to 167 \to 173 \to 179$. $k = 173$ corresponds to the size of the cell 20 μm. $k = 179$ corresponds to the size 160 μm of a large cell, for example a neuron.

2. $d = 2$-dimensional case predicts $\Delta k = 4n$ as the density increases by a factor of 2^n and scaling by $1/2^n$ occurs. These transitions would be associated with bilayered structures. $k = 137 \to 149 \to 157 \to 169 \to 173$.

3. $d = 1$-dimensional case predicts $Deltak = 2n$. The transitions $k = 137 \to 139$, $k = 149 \to 151$ (cell membrane $\to$ layer-neuronal membrane) and $k = 167 \to 169$ are possible in condensed matter scales.

The hypothesis that the prime values of k are favored and the the density of repulsive energy at least decreases in the scaling transition implies that the biologically important p-adic length scales emerge as scales of quantum coherence in the transition.

2.5 Could quantum geology make sense?

The Equivalence Principle and gravitational quantum coherence imply that the analog of the harmonic oscillator model for nuclei could make sense. The particles would oscillate in unisono irrespective of their mass: a kind of gravitational Bose-Einstein condensate would be in question. The obvious questions are whether the layered structure of the Earth could be understood in terms of this model and whether the proposed contraction and expansion phases for the Earth could be understood in terms quantum transitions between the oscillator states.

2.5.1 Could the Earth be modelled using the analog of the harmonic oscillator model for the nucleus?

I have previously discussed a quantum model for the dynamics of blackholes and stars starting from the harmonic oscillator model for the nuclei.

1. Constant density gives rise to gravitational harmonic oscillator potential. I have already earlier studied a quantum harmonic oscillar model of stars and blackholes [L18]. The harmonic oscillator model for the Earth is a good starting point of quantum geology. In principle, one must take into account also the condensed matter interactions. The treatment of the Earth as an elastic sphere can serve as a starting point. The basic idea is that the layers of the Earth could correspond to harmonic oscillator states for the radial harmonic oscillator and perhaps even for a rigid body oscillator so that also the Euler angle would appear as degrees of freedom.

2. By Equivalence Principle, realized via gravitational Planck constant, the Bohr orbit radii r_n does not depend on the mass m at all and can correspond to a mass of any particle like object belonging to a given layer, assuming quantum coherence is true. Therefore the many particle states for a gravitational quantum coherent state are analogous to a Bose-Einstein condensate. This suggests that the compression and expansion of the Earth radius could be interpreted as quantum transitions between harmonic oscillator states involving a transfer of particles between different oscillator states.

3. In the harmonic oscillator model for nuclei, one assumes harmonic oscillator potential and Hartree-Fock approximation assuming that the harmonic oscillator potential provides an effective description for the many-nucleon system.

4. In the case of stars and planets like Earth, the mass density is in a reasonable approximation constant so that the gravitational potential is harmonic potential so that a similar approximation is suggestive. If one assumes $\hbar_{eff} = \hbar_{gr}(M_E, m) = r_s m/2\beta_0$, the energy is given by $E = \hbar_{gr}\omega = \hbar_{gr}\omega = \hbar_{gr}\sqrt{k/m} = r_s\sqrt{km}/2\beta_0$.

5. For the gravitational potential energy

$$V_{gr}(M, m) = \frac{r_s m}{2R_E}(-3 + \frac{r}{R_E}^2) \quad .$$

. The constant part means gives only an additive constant in the energy and the effective elastic constant is given by

$$k = \frac{r_s m}{2R_E^3} \quad .$$

and

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{r_s}{2R_E}}\frac{c}{R_E} \sim 1.3 \times 10^{-3}\mathrm{Hz} \ .$$

This corresponds to a period of 12.8 minutes.

6. If the gravitational force dominates, the oscillations occur in unisono for all particles independently of their mass so that one has an analog of Bose-Einstein condensate. This reflects the Equivalence Principle. The oscillator energies are proportional to the masses of the particles and the total oscillator energy is given by $E_{tot} = (1/2\beta_0)(r_s/R_E)^{3/2} \times M_E \sim 10^{-13-1/2}M_E$.

   For non-gravitational interactions the k is not proportional to m so that both ω and E depend on m .

7. The small value of the oscillator period implies that the recoil effect cannot be interpreted classically as an excitation of harmonic oscillator. The same is true quantally.

   Using the analogy with nucleus, one can however consider a description in terms of many particle states for a gravitational harmonic oscillator. The idea would be that the particles with higher values of the principal quantum number n are pushed to states with a smaller value so that the radius of the Earth decreases. The time spent in the lower energy states can be quite long and the master slave-dynamics dictates this time scale.

8. This inspires the question whether the layers of the mantle of the Earth could in some way correspond to the states of the gravitational harmonic oscillator. In other words, could the layers of mantle as counterparts for the harmonic oscillator states labelled by a small principal quantum number n? The expression for the orbita radius r_n is given by

$$\begin{aligned} r_n &= \sqrt{2n+1}\sqrt{\hbar_{gr}/m\omega} = \sqrt{2n+1}\sqrt{\tfrac{r_s}{\omega}} \\ &= \sqrt{2n+1}\,\tfrac{r_s}{R_E}^{1/4}R_E \simeq \sqrt{2n+1} \times 6.325 \times 10^{-3}R_E \end{aligned}$$

   The natural scale is $\sim$ 40 km and would define the distance between the energy shells in the deep interior. The condition $r_n = R_E/2$ can be satisfied for $2n+1 = (R_E/r_s)^{1/2}/4$ giving $n \simeq 3.1 \times 10^9$ so that the classical limit of harmonic oscillator would be in question so that the idea fails. This would give $(dr_n/dn)/r_n \simeq \sqrt{2/n}$. At $r_n = R_E/2$ this would give $r_{n+1} - r_n \simeq 1$ mm.

2.5.2 Could fractality of the harmonic oscillator make possible to assign mantle layers to harmonic oscillator states?

The harmonic oscillator model as analog of the harmonic oscillator model for nuclei predicts that the states of gravitational quantum oscillator correspond to the large quantum number limit except in the interior. Description in terms of small oscillator quantum numbers might however allow us to understand the layered structure of the mantle. Could some kind of renormalization procedure allow description in terms of finite measurement resolution?

1. The harmonic oscillator is fractal in the sense that the spectrum contains harmonic oscilattor states as sub-spectrum. For Bohr orbits radii are proportional to $\sqrt{2n}$ and the subspectrum for which n is multiple of integer r defines a spectrum of radii scaled by $\sqrt{r}$. For quantum states the radii are proportional to $\sqrt{2n+1}$ and the integers defined by $m = (2r+1)n$, where r is fixed and n varies, defines a subpectrum. This also relates interestingly to measurement resolution. Could the bands correspond to a finite measurement resolution lumping the states of the band to a single state.

   This kind of fractality is encountered also for the super-conformal algebras and defines a fractal hierarchy of symmetry breakings of the algebra to an isomorphic sub-algebra. This hierarchy is essential for quantum TGD [L21, L22] [K4]. An interesting question is whether there is a connection with the breaking of conformal symmetry in this sense. Could this kind of symmetry breaking be needed to give a spectrum with radii larger than R_E?

2. This inspired the idea that a subset of harmonic oscillator states with principal quantum number n coming as multiples km of integer k and defining similar subspectrum could give a useful description in the sense that the layers of the mantle could correspond to the bands defined by the values of n in the range $k[m, m+1]$ and correspond effectively to a single value of n for a scaled oscillator energy. This brings to mind the notion of the energy band used in condensed matter physics.

3. This idea is probably too simplistic but one can start with it. For instance, the upper layer of the mantle decomposes to crust, lithosphere and asthenosphere. Since the states of gravitational harmonic oscillator define Bohr orbit radii assignable to single particle states irrespective of mass, one can ask whether the layers of the Earth could be analogous to energy bands appearing in condensed matter physics and whether fractal decomposition of layers to sublayers could have an elegant description in terms of harmonic oscillator energy bands. Could the geometric separation between the layers correspond to missing bands of harmonic oscillator states so that they would be like holes in the condensed matter electron system?

   By Equivalence Principle, the oscillator frequency ω does not depend on the mass of the basic unit, it would be natural to introduce the notion of measurement resolution and consider different views based on different choices ΔM of the mass unit defining also radial spatial resolution ΔR as the thickness of the layer. The two resolutions are identical when logarithms of R and M are used as variables as in the usual renormalization theory: $\Delta ln(R) = 3\Delta ln(M)$. The frequency ω would be invariant under renormalization.

4. The idea that a subset of harmonic harmonic oscillator states corresponds to the layers of the Earth can be tested. Consider the states with $n = 1, 2, 3, 4$ with radii

$$R_n \equiv r_{(2r+1)n+1}\frac{(2r+1)n+1)}{2(r+1)}R_E/2 \quad .$$

   Assume that the condition $R_1 = r_{2r+1} = \sqrt{2r+2}R_E/2$ is satisfied. For large values of r one has in good approximation $R_n \simeq \sqrt{n}R_E/2$ as for the states of the harmonic oscillator.

   The radius of the core is 55 per cent of the solar radius and slightly larger than $r_2 = R_E/\sqrt{2} \simeq 4.504$ Mm, which corresponds to the depth $d = 1.871$ Mm and does not have any obvious counterpart in the mantle. $R_3 = R_E\sqrt{3/4} \simeq 5.516$ Mm corresponds to $d = 859$ km to be compared with the depth of the lower boundary of upper mantle is 660 km).

2.5.3 What does one mean with quantal time evolution of the Earth?

The creation of Moon and CE in terms a "big" state function reductions (BSFR) provides the basic quantum description. What is new that in the BSFR the arrow of time is reversed [K5] [L5]. One can imagine two basic options.

1. Only single BSFR occurs. The formation of the Moon in the first explosion would have been the first BSFR and CE would have been the second BSFR in which the original arrow of time was established. This option leads to a rather surreal vision which I tried to formulate in [L29, L25, L34].

   There would have been a 4 Gy period of time reversed evolution. This would be like falling asleep for 4 Gy years. Then sudden step to future took place as the boundary of CD was effectively replaced by the opposite boundary. Highly evoled multicellulars emerged in the second BSFR as the water undergound bursted to the surface. Effectively this was a moment of creation. The detailed realization of the new view of geometric time is highly challenging since it is in a sharp conflict with intuition. The attempt to understand known facts about geological evolution poses problems.

2. A pair of BSFRs occurs in both the creation of the Moon and in CE. Both events would be like short naps. This option looks much more realistic. The pair of BSFRs corresponds by quantum-classical correspondence to a classical space-time evolution dictated by holography= holomorphy principle and this gives strong conditions. The geometric duration of the period

with an opposite arrow of time corresponds to the time scale of an appropriate causal diamond (CD). For the Earth size scale the duration of CE would have been too short, of the order of 10^{-2} seconds which looks quite too short. For the Sun it would be about 8 minutes. The thickness of the Milky way gives an estimate of $T = 1000$ ly and the horizontal size scale of $T = 100,000$ y. The option based on pairs of BSFRs as analogs of quantum tunnelling seems to be the only plausible option.

There could have been several steps in the contraction of the Earth radius between the creation of the Moon and CE and in the expansion of the Earth after CE.

1. These events could correspond to major events in biological and geological evolution. During the expansion phase one such event could be the emergence of plate tectonics as the splitting of the rigid crust to tectonic plates. During the compression phase the mountains could have formed in the contraction phase as the plates would have collided. Mountains with age longer than .5 billion years could have formed in this way whereas young (10 to 80 million years old) would have formed by the standard mechanisms. Famous examples include the Appalachians (approx. 480 million years old) and possibly slightly before or after the CE and the Barberton Makhonjwa Mountains in South Africa (up to 3.6 billion years old), which would have formed during contraction period.

2. The quantum model of gravitational harmonic oscillator with gravitational Planck constant allows to consider a simplified quantum model in which the expansion corresponds to a pair of rapid transitions $n_1 \to n_1 + 2 \to n_1 + 3$ between harmonic oscillator states in which the radius increased as $R_E/2 \to sqrt3 \times R_E/2 \to R_E$. These would correspond to the radii of the Earth's core, radius of the upper mantle and the Earth. The opposite sequence would be true for the compression and by angular momentum conservation coupling the dynamics of the Earth and Mars correspond also to rapid momentum transfers by pairs of BSFRs with the Moon.

2.5.4 How to understand the emergence of plate tectonics?

Geological evolution involves the creation of the Moon and CE as two major events.

1. If each corresponds to a single BSFR, one ends up with difficult conceptual challenges. If they correspond to pairs of BSFRs with geologically short geometric time intervals between them, the situation changes. Both the contraction phase and expansion phase could involve more BSFR pairs assignable to important geological events.

2. The contraction period should correspond to the transfer of protons by Pollack effect to the gravitational magnetic body and generation of a dark silicate ion phase. This phase transition could have been energized by the formation of dark variants of nuclei. DNA, RNA and cells containing negatively charged EZs would be energetic analogs.

   The despised "cold fusion" (LENR) would have been the key event of the history of Earth. In fact, Prof. Leif Holmlid suggests on basis of experimental work that "cold fusion" involves the formation of an ultradene phase [C1] leading to the generation of dark nuclei in turn decaying to the ordinary nuclei. The TGD based model is based on Pollack effect [L1, L24]. The distance between protons/deuterium nuclei is about 2.3 pm, which is of the same order of magnitude electron Compton length 2.42 pm and much shorter than the distance about .5 Å s in the Pollack phase with an 8-fold density.

3. The structure of the mantle suggests that the contraction occurred in two steps. First Pollack phase transition occurred for the upper mantle and after that for the lower mantle. The order of steps would have been opposite during the expansion period.

Plate tectonics provides guidelines helping to develop a more detailed view.

1. The standard narrative is that plate tectonics emerged between 3.5-3.2 Gy years ago. The evidence for this comes from paleomagnetism: the ancient crustal blocks would have drifted rapidly and rotated poleward. Studies of titanium isotopes and silica-rich content in ancient

shales indicate that the continental crust underwent significant recycling and chemical processing. This highly evolved, silica-rich crust is a telltale sign of subduction-driven tectonic activity. The presence of distinct, juxtaposed rock formations and sedimentary basins from the Archean Eon suggests early crustal collisions, rifting, and the buildup of mountain belts before they were eroded.

2. The difficult-to-understand fact is that the continental plates associated with the oceans have very different composition than those associated with the continents.

Let us now try to imagine what happened.

1. For the two-step quantum option, the transition $n = 1 \to 3$ implying the scaling $R_E/2 \to \sqrt{3}R_E/2 \simeq .885R_E$, from the radius slightly below the recent core radius to the radius $.885R_E$ of the radius of the lower mantle. The second step would have induced the scaling $.885R_E \to R_E$.

2. During the contraction period, both crust and upper mantle would have formed connected structures analogous to paper sheets and would have generated wrinkles in the contraction. One can also imagine that protoplates exist and their collisions created the old mountains. The wrinkles would correspond to mountains older than .5 Gy. The sheets would have been split into pieces during the expansion phase(s).

3. For the 1-step-only option, the rapid expansion of the Earth radius would have started for .5 billion years ago and separated continental protoplates. This does not conform with the empirical findings.

4. For the two-step scenario, the first step would have transformed the matter of the lower mantle to ordinary matter and pushed the upper mantle outwards. It could not stretch the upper mantle in the tangential directions since the reverse Pollack phase transition would have occurred. Therefore the upper mantle was split into plates and generated the oceanic plate tectonics. At the second step, as the reverse Pollack effect for the upper mantle, oceans containing multicellular life bursted to the surface in the Cambrian explosion. The rigid crust was split to continental tectonic plates.

It is convenient to use instead of time coordinate t for the event n the difference $t_n = t_{now} - t$ so that event occurred t_n ago. Let us estimate the times t_n for the transition sequence $n = 1 \to 2 \to 3 \to 4$ as expansion and its reversal as contraction assuming that the times relate linearly to the ratio R_n/R_E. As proposed the two-layered structure of the mantle could correspond to 2-step sequence $n = 1 \to 3 \to 4$ but in the following the entire 3-step sequence is considered.

Assume that the minimum radius occurs in the middle of the 4 Gy period between the formation of the Moon and CE so that $t_{min} = 2.5$ Gy corresponds to the minimum radius $R_{min} = R_E/2$ and $t_{max} = 4.5$Gy to the maximum radius $R_{max} = R_E$ occurring in the beginning and end of the sequences consisting of contractions and expansions. The formula for the transition times reads as

$$t_n = t_{min} + (t_{min} - t_C)(1 - \frac{R_n}{R_E}) \ ,$$

where $t_C = .5$ Gy corresponds to the time of CE.

During the contraction period one has

$$\frac{R_n}{R_E} = (1, 1/\sqrt{2}, 1/\sqrt{3}, 1/2) \ ,$$

$$\frac{t_n}{Gy} = (4.5, 4.19, 3.67, 2.5) \ .$$

During the expansion period the radii are

$$\frac{R_n}{R_E}(1, \sqrt{2}, \sqrt{3}, 2)/2 \ ,$$
$$\frac{t_n}{Gy} = (2.5, 2.7, 0.7, 0.5) \ .$$

Oceanic *resp.* continental plate tectonics would have most naturally emerged at $t_n = .7$ *resp.* $t_n = .5$ Gy. This prediction does not conform with the estimate of the standard narrative that

plate tectonics emerged 3.5 to 3.2 billion years ago. Contraction period could have however caused wrinkles and give rise to old mountains so that the mechanism would be different from plate tectonics. The time 3.67 Gy is consistent with the standard estimate for the emergence of plate tectonics.

2.5.5 Qualitative predictions of the model

The model leads to many non-trivial qualitative predictions. Consider first the contraction phase.

1. Miller-Urey pathway requires the presence of oceans in the beginning. In the transition to Pollack phase for silicate, the pressure and temperature of the magma dropped dramatically and the water at at the surface, perhaps generated by the mechanism proposed in [E1], was swallowed underground and underground water reservoirs and perhaps even oceans were formed. The recent situation on Mars indeed supports this view. There is indeed clear evidence that Mars has had oceans.

2. Contraction could explain the formations of old mountains older than .5 Gy as formation of "wrinkles" during the contraction phase. Contraction would have created these wrinkles also at the surface of the core and the mountains at the surface of the core have been discovered [D1] [L10]. The standard explanation is in terms of the tectonic activity circulating matter between the ocean floor and the surface of the core.

3. Great Oxygenation Event (GOE) is estimated to have occurred 1-3 Gy ago. In the proposed model GOE would have occurred in the interior of the mantle in underground water reservoirs and the layers in the ocean crust would have belonged to the interior of the Earth. It is difficult to decide whether GOE took before the minimum $R_E/2$ estimated to have occurred 2.5 Gy ago, at the minimum, or after it.

   The evidence for the oxygenation comes from many sources (see the Appendix), in particular the presence of the red layers below in the continental crust. Due to subduction, the age of the ocean crust is only .2 billion years. The red layers used as geological evidence for GOE are primarily found in continental or shallow-marine sedimentary rock sequences (such as terrestrial red beds and banded iron formations). These ancient, oxidized rocks—dating back roughly 2.4 to 2.2 billion years ago—are typically exposed on the surface or buried at shallow depths within continental cratons today. The natural explanation would be that, although the GOE occurred in the interior, there was an exchange of water between interior and the surface. The red planet Mars which has had oceans but does not have them now would serve as an example of this exchange.

Consider next the expansion phase.

1. A natural idea is that oceans were formed in the splitting of the upper and lower mantle. Ocean depths are typically 3.6 km, 11 km is an upper bound. This scale is that of the crust thickness suggesting that they were formed when the upper layer of the mantle was split into continents in the expansion and the transversal expansion fored the rigid crust to split into pieces.

   This suggests that the expansion of the lower layer of the mantle, whose upper surface is at the depth $d = .1R_E \sim 637$ km, did not break the layer above it to pieces although it caused tangential stretching. If the splitting occurred and the water from the lower layer filled the resulting fractures, the recent oceans would have a depth of order d. This would suggest that at the first step, the upper layer decomposed into regions consisting of ordinary silicate and its Pollack phase.

   The upper layer decomposes to hotter, flowing asthenosphere and rigid litosphere. The thickness of the oceanic litosphere varies from 5 km to 100 km and the contents of continental litosphere varies from 100 to 250 km. This forces to ask whether the proposed quantum model is too simple and whether the expansion could have had additional steps corresponding to the substructure for the layers of the mantle.

2. Traces of life in deep mantle [L7]. The popular article titled "Traces of life in the Earth's deep mantle" in Phys-Org (`https://cutt.ly/AAIj7Ss`) told about the work of Giuliani et al about discussed in the article "Perturbation of the deep-Earth carbon cycle in response to the Cambrian Explosion" [F1] (`https://cutt.ly/wAIko6S`).

   The sudden emergence of advanced multicellular lifeforms in the Cambrian Explosion (CE) about 540 Ma ago is still one of the great mysteries of mainstream biology. The team led by ETH researcher Andrea Giuliani found in rocks from deep mantle what can be regarded as traces of CE. The proposal is that partly organic material would have been subducted to the deep mantle after CE and changed the isotopic compositions of Carbon and other elements. Also other elements, for instance strontium and hafnium showed a pattern similar to carbon.

   The group of Giuliani examined rare diamond-containing volcanic rocks known as kimberlites from different epochs of the Earth's history. These special rocks originate from the lowest regions of the Earth's mantle. The isotopic composition of carbon in about 150 samples of these special rocks was determined. The composition of younger kimberlites, which are less than 250 million years old, was found to vary considerably from that of older rocks. In many of the younger samples, the composition of the carbon isotopes differs significantly from that expected for typical rocks from the mantle.

Also the evolution of magnetic fields is of high interest.

1. In the TGD framework monopole magnetic fields carrying dark matter are in a central role. According to the Mawellian view the magnetic field of Earth should have disappeared a long time ago: the basic reason is the dissipation of the electric currents creating it. The magnetic field of Earth would consist of the ordinary Maxwellian part having currents/magnetic dipoles as its sources and the monopole flux tube part of strength about .2 Gauss, the "endogenous" magnetic field essential for life.

   The flux conservation for the monopole part would take care of the [L2] of the preservation of the magnetic field. Ordinary magnetic fields could be regarded as being induced by the motion of the monopole part inducing currents. Also now an energy source for the necessary currents is needed and the dynamo model could provide it. The changes for the orientation of the magnetic field would however involve temporary decay of the monopole flux tubes to short flux loops by reconnections [L14, L15]. This kind of decay might have occurred on Mars so that only local fields have been preserved.

2. There is evidence that Earth had large scale magnetic fields already 3.7-4.2 Gy ago from zircons. Zircons are incredibly durable microscopic crystals used by geo-scientists to study the ancient geomagnetic field. When zircons form, they can trap tiny magnetic minerals (like magnetite) that align with Earth's magnetic field, creating a "fossilized" record of the planet's magnetism. However, the use of zircons in paleomagnetism remains highly debated in the scientific community. One could think that monopole flux tubes could have induced magnetization giving rise to zircons. Gravitational monopole flux loops could have been in question and monopole flux loops tangential to the Earth appear in the TGD model for the orientation reversal of the Earth's magnetic field and also solar magnetic field [L14, L15].

3. It is thought that the solidification of the Earth's inner core occurred about .5 Gy ago as an outcome of cooling. What is interesting is that CE as the last step in expansion of the Earth would be around this time. In the dynamo model, the energy liberated by it would make possible the currents generating the magnetic field in the dynamo model. The increase of the strength of the magnetic field would have made it a shield for the life that bursted to the surface.

   If one takes the time .5 Gy literally and the transition indeed occurred in two steps, the first step would have already occurred and the lower layer of mantle would have been in ordinary phase. The second option is that the solidification occurred at the first step. One can also argue that the phase transition from the Pollack silicate to the ordinary silicate occurred because it liberated dark nuclear energy.

4. It is not clear whether the monopole flux tubes are detectable in recent technology. The magnetization caused by them could be however detected. U-shaped radial gravitational monopole flux tubes should be present also in Mars since they should mediate the gravitational interactions. The radial character is what possibly makes it possible to differentiate between the gravitational monopole magnetic fields from Maxwellian ones. What is interesting is that auroras have been observed in Mars: could they be regarded as signatures for the presence of the monopole flux tubes? There is also evidence for local magnetic fields on Mars.

2.5.6 A model for the coupling of the dynamics of the Moon and Earth

It is interesting to build a model for the dynamics of the Moon assuming that the total angular momentum of the Moon-Earth system is conserved. It is also interesting to check what gravitational Bohr orbitology gives in this framework.

1. Angular momentum conservation for the orbit of Moon in the final stage when Moon and Earth are in good approximation decoupled

$$\omega_M^2 = \frac{r_{s,E}}{2R_M^3} \quad .$$

Here the subscripts M *resp.* E refer to the Moon *resp.* Earth.

2. Angular momentum conservation states that the total changes of the angular momentum for the Earth and Moon are opposite. The initial angular momentum of the Moon can be neglected and one objects

$$\Delta L_M \simeq M_M \omega_M R_M^2 \quad .$$

The Earth's rotation velocity ω is assumed to stay constant until CE occurs and is $\omega_E = 4\omega_{now} = 1/6$ hour^{-1} corresponding to the duration 6 hours for the day. The change of the Earth's angular momentum is

$$\Delta L_E = \frac{3}{4}\frac{2}{5} M_E \omega_E R_E^2 \quad .$$

3. The conservation condition gives

$$\frac{\omega_M}{\omega_E} = \frac{6}{5}\frac{M_E}{M_M}\left(\frac{R_E}{R_M}\right)^2 \quad ,$$

which gives for the angular momentum of the Moon the expression

$$L_M = \frac{6}{5}\frac{M_E}{M_M} M_M \omega_E R_E^2 \quad .$$

4. The condition $L_M = n\hbar_{gr}(M,E)$ gives

$$n = \frac{12}{5}\frac{M_E}{M_M}\frac{R_E}{r_s}\frac{\omega_E}{c}\beta_0 \quad .$$

5. Bohr quantization condition $L_M = h\hbar_{gr}$ for the angular momentum of Moon-Earth system with $\hbar_{gr} = M_M r_{s,E}/2\beta_0$ gives

$$n \simeq 1.2496 \times 10^5 \beta_0$$

so that large quantum number limit is in question. For Earth $\beta_0 \simeq 1$ is a good approximation. where $R_M \simeq 60 R_E$ and $\omega_E/\omega_M \sim 27$ have been used.

6. Bohr orbitology gives for the radius of the Moon orbit

$$R_M = n^2 a_{gr} = \frac{n^2 r_s}{2\beta_0^2} \quad .$$

Using $R_M \simeq 60R_E$, this gives the same condition for n as the quantization of angular momentum.

2.6 A possible view of biological evolution of the Earth

The view about the geological evolution of the Earth leads to the following narrative about the geological and biological evolution of the Earth [K2] [L29, L34]. This narrative, which had several problems, served as a basis for the view discussed in this article. In particular, the question whether the entire period from Moon's creation to CE had a reversed arrow of geometric time turned out to have a negative answer.

1. The first basic idea is that at the beginning of the Earth's history, about 4.5 billion years ago, the Moon was born in an explosion that threw the Earth's surface layer into the sky. This idea is crazy but not crazier than the assumption that a planet the size of Mars, christened Theia, collided with the Earth. Even better, the TGD view is consistent with the fact that Moon's and Earth's compositions are identical.

2. The contraction of the Earth, induced as a recoil effect due to the formation of the Moon, would have induced a phase transition in which the density of the Earth would have increased by factor 8, most naturally in two steps involving scalings of the radius R_E by factors $1/\sqrt{3}$ and $\sqrt{3}/2$. so that the final radius was $R_E/2$.

   The quantum description of these transitions is in terms of the quantum harmonic oscillator model as collective transition for Bose-Einstein type gravitational condensate particles. The Equivalence Principle coded to the form of gravitational Planck constant is what makes the quantum coherent co-existence of particles with different masses.

   Various ions neutralizing the silicate lattice would have been transferred by Pollack effect to the gravitational magnetic body forming stable dark nuclei there and making this phase energetically favored. Charge separation would have been between the Earth and its gravitational magnetic body. This transition would have reduced dramatically the number of the translational degrees of freedom contributing to the pressure so that the phase would have had pressure allowing life to develop inside water pockets. Also the temperature could have been low enough for the survival of basic molecules.

3. The basic molecules of life and possibly existing primitive life forms would have been transferred to underground oceans during the contraction phase. This would be the TGD counterpart for the formation of oceans by the penetration of high pressure H_2 to the magma as the article suggests (see this).

   Interestingly, the amount of water formed in the experiments [E1] was 1000 times larger so that one can ask whether the Pollack phase transition took place also in these experiments. There it was, as it were, in a warm womb, safe from cosmic rays and meteorite bombardment.

4. Multicellular life and photosynthesis, utilizing radiation from the core as metabolic energy instead of sunlight (Pollack effect) or possibly arriving along gravitational monopole flux tubes from the Sun as dark photons, evolved in subterranean oceans.

   The underground life could have bursted to the surface either in a single step in the Cambrian explosion .5 billion years ago or in two steps. For the first option the Earth's radius would have increased by a factor of 2 in a geologically short time scale. By angular momentum conservation the length of the day increased by a factor of 4 from about 6 hours. For the 2-step option , the length of the day would have increased by factor 3 to 18 hours in the first and to 24 hours in the second step.

5. Both options explain the scarcity of observations of fossils of organisms intermediate between bacteria and multicellular organisms before CE. If the expansion took in two steps, the upper magma layer would have decomposed into oceanic plates in the first and oceans would have formed as part of the underground water bursted to the surface. Oceanic life would have emerged at the first step.

   If the times T_n of the steps like the radii R_n of the Earth created in these steps, one has $T_{first} = \sqrt{32} \times .5$ Gy $\sim .4$ Gy. In the second step, the crust was decomposed into pieces and more oceans would have been formed.

6. Assuming that multicellular life evolved inside the Earth, it would have first led to the emergence of plants which almost always have roots in the soil. There are also plants, whose roots are in air or water. For instance, algae, appearing both as unicellulars and multicellulars, have roots in water. Ordinary soil consists of mineral particles (sand, silt, clay), water, air and organic particles such as proteins.

   Could Pollack counterpart of SiO_4O^{4-} (quartz) bounding the underground water reservoirs having SiOH at the walls have served the role of the proto soil, which then evolved to the analog of ordinary soil as the material produced by the dead organisms? The walls could have been covered by gel-like SiOH, which is hydrophilic and allows Pollack effect and could catalyze it. SiOH can also induce generation of water in presence of H_2. For ordinary silicate this requires a temperature higher than 150 °C but for the Pollack counterpart of the silicate the temperature might be at the physiological temperature range.

The underground evolution of life in the Pollack phase raises interesting parallels with the religious myths.

1. The Pollack phase during the contraction phase had quantum coherence in the Earth scale and had low temperature and pressures despite the high density. The interior of the mantle was a paradize since the dissipation was minimal. This conforms with the idea about underground water reservoirs and oceans as a womb of Mother Gaia.

2. The end of this period was very analogous to birth and meant childhood's end and expulsion from the paradize and in the sequel only DNA, RNA, and cell interiors were the places where quantum coherent Pollack phase existed.

3. Why was the quantum coherence in the Earth scale lost? The physical explanation would be in terms of the instabilization of the Pollack phase (due to the presence of dark nuclei at the gravitational magnetic body). The myth of Adam and Eve provides a religious explanation for what happened as a penalty of God for not obeying God's orders. Adam and Eve lost the innocence of a child. What could this mean using the language of physicists?

   Life evolved in the womb of Mother Gaia and eventually the animal kingdom emerged. Animals used plants and other animals as food and became predators. Paradize was not anymore a safe place. Did this lead to the loss of trust and destruction of quantum coherence as it would also do in the society? Stable Quantum entanglement is essential for the absence of dissipation and makes possible large quantum coherent structures.

2.6.1 Connection to the plasmoid life

TGD suggests [L11] that the chemistry based life was preceded by plasmoid life that evolved in the upper atmosphere and later was transferred to the Earth, for instance during thunderstorms as ball lightnings. This proposal was inspired by the general TGD based views and the empirical findings reported by Rhawn and Schild in Researchgate. Quite recently their article representing detailed experimental findings supporting the notion of plasmoid life emerged [I3] was published in the Journal of Astrobiology.

pport the view that plasmoids in the sense of TGD [L11] could have preceded chemical life.

1. The behavior of the studied objects suggests monopole flux tubes. In the Maxwellian world currents are needed to maintain them and dissipation forms a problem. The Maxwellian flux tubes are also unstable against pinch and various other instabilities. Monopole flux tubes do not require external currents and the conservation of the monopole flux stabilizes them [L2].

2. Evidence was found for the replication of flux tubes. Monopole flux tubes with a monopole flux higher than one unit can replicate. TGD predicts a universal mechanism for the replication of space-time surfaces. In this case the monopole flux tube would turn backwards in time. This would also make possible DNA replication: the two new strands generated in the replication would correspond to a DNA strand turning backwards in time.

3. Metabolic homeostasis via environmental current processing was observed. Zero energy ontology makes possible homeostasis as an ability to stay near quantum criticality by making "big" state function reductions reversing the arrow of geometric time. When the system starts to fall from the top of the hill, a BSFR occurs.

4. No carbon chains would be present so that non-chemical life was in question. The view about plasmoids as predecessors of chemical life is also supported by the fact that cold plasmas formed by various ions could be an essential element of biological life.

During the compression period, the ions neutralizing the silicate lattice were transferred to the gravitational magnetic body by the Pollack effect, which suggests that plasmoid life evolved there and started to control the evolving biological life. During the expansion period part of the ions were transferred by reverse Pollack effect to the silicate lattice.

One can also ask how large a fraction of these neutralizing positive alkali and metal ions was present in the beginning. Could one consider the possibility that protons and helium ions dominated and dark fusion at the gravitational magnetic body gave rise to heavier ions?

2.6.2 Connection to the idea about conscious computers

The idea of quartz life [L20] inspired the proposal discussed here. The motivation behind the notion of quartz life was the question whether computers could be or become conscious in some sense. The question was whether the Pollack effect for silicate lattice involves OH bonds able to transform to O^- + dark protons at the gravitational magnetic body could make ordinary computers hybrids of quantum - and ordinary computers. The transistors of ordinary computers often have a surface layer consisting of SiOH which suggests a control mechanism in which the magnetic body can control the charge of the base of a transistor by Pollack effect and in this way the classical bit of the transistor.

This inspires the question whether the phase transition transforming ordinary silicate lattice to its Pollack counterpart could be induced by pumping energy to the system (as a counterpart of the high pressure in the experiments of Horn et al [E1] and lead to a stable EZs and dark proton and ion condensates at the magnetic body. This would be like mimicking the evolutionary steps leading to the emergence of chemical life. One can also ask whether the Pollack silicate could form a conscious entity in the scale of the Earth during the contraction period of the Earth.

3 Appendix: The standard view of geological and biological evolution of the Earth

In the following the standard view of the geological and biological evolution of the Earth is summarized and some TGD inspired comments are made. I hope that this summary could make it easier for the reader to check whether the TGD narrative makes sense.

3.1 Geological evolution and evolution of atmosphere

The magnetic body of the Earth and the space-time sheets associated with the Earth itself can have different arrows of time. If the arrow of the geometric time of the magnetic body changes only during a geologically short time interval during the key events associated with the contraction and expansion phases, ZEO does not produce interpretational challenges. The geological evolution would correspond to the classical time evolution associated with a superposition of the space-time sheets generated in Cambrian BSFR extending to the moment when Earth was created and the standard interpretation of the results of the timing would make sense except during the geologically short periods with reversed arrow of time.

In the sequel the standard narrative, constructed with the help of Google Gemini (I am not a professional geologist of biologist), is represented with comments comparing this narrative to the TGD view.

3.1.1 How did crust evolve?

Earth's first rocky crust (see this) solidified very quickly after the planet's formation, cooling to form a primitive protocrust between 4.5 and 4.4 billion years ago. The buoyant, granite-like continental crust we live on today took longer to emerge, with significant amounts forming and stabilizing between 4.0 and 3.8 Gy ago. Extracted from an extensive, early magma ocean, this initial crust was unstable, frequently melted by heavy asteroid bombardments, and has since been almost entirely destroyed or recycled into the mantle.

1. The primitive protocrust (4.5 to 4.4 Gy ago): Shortly after the Earth formed about 4.54 Gy ago, its surface was covered in a boiling magma ocean. As the planet cooled, the outermost layer solidified into a dark, basalt-like rock. Zircon crystals found in the Jack Hills of Australia have been dated to 4.4 Gy ago and prove that a solid crust existed just 160 million years after the solar system formed.

2. The first continents (4.0 to 3.8 Gy ago): Water interacting with the early, hot oceanic crust caused it to melt and re-melt, separating lighter minerals (such as silica and quartz) from heavier elements. This created buoyant, granite-like rocks that floated higher on the mantle than the dense basalt, forming the very first stable landmasses (cratons). Some of the oldest known preserved rocks, like the Acasta Gneiss in Canada, date to about 4.0 Gy ago.

3. Emergence above sea level (3.7 to 3.5 Gy ago): Geochemical studies of ancient barite and shale minerals show that continental rock was actively weathering and eroding into the oceans as early as 3.7 to 3.5 Gy ago. This indicates that large, stable sections of the crust had successfully emerged above sea level.

4. The onset of plate tectonics (3.5 to 3.2 Gy ago): For the first few hundred million years, the crust may have existed as a single, unbroken "stagnant lid". Studies suggest that modern plate tectonics where the crust breaks into shifting puzzle pieces began somewhere between 3.5 and 3.2 Gy ago.

TGD inspired comments The circumstances at the surface of the Earth during the Hadean era and immediately after it support the idea that life evolved in underground oceans.

1. The basic biomolecules could have emerged by the Miller-Urey pathway in oceans but were the oceans at the surface of the Earth or in the interior? For both options the water could have been generated by the mechanism proposed in the article of Horn [E1]. If the water bursted to the surface and formed surface oceans, the formation of Pollack silicate would have swallowed the oceans.

   The alternative option is that Miller-Urey process took place in underground oceans formed in Pollack silicate. The observation that the amount of water formed was 1000 larger than expected justifies the consideration of the latter option.

2. The objection against the Pollack option is that the nitrogenation splitting N_2 molecules to N atoms is needed to produce ammonium NH_3 needed by the Urey-Miller process and requires lightning and volcanic activity. In the TGD based model for lightning, the currents flow with very small dissipation along gravitational magnetic monopole flux tubes with large h_{eff} and can extend below the surface of the Earth.

   There is empirical evidence that lightning strikes are accompanied by electrons and gamma rays in the MeV energy range discussed in [K1]. This is not possible in the standard model and supports the view that they arrived without dissipation along monopole flux tubes.

3. The second objection is that solar radiation is needed as metabolic energy. Could it have arrived along gravitational monopole flux tubes or could the core of the Earth have served as an artificial Sun providing the dark photon radiation serving as metabolic energy?

3.1.2 The first atmosphere

The very early atmosphere of Earth absolutely contained molecular hydrogen (H_2) gas. In fact, planetary scientists categorize Earth's early history into two distinct phases of atmosphere, both of which featured hydrogen.

1. The primordial atmosphere ($\sim$ 4.6 to 4.5 Gy ago): The primordial atmosphere was Earth's very first "atmosphere," consisting almost entirely of hydrogen (H_2) and helium (He). These light gases were swept up directly from the solar nebula the massive swirling disk of gas and dust that formed the sun and planets. This atmosphere did not last long. Because Earth is relatively small and was incredibly hot at the time, the low-mass H_2 molecules moved too fast for Earth's gravity to hold onto them. Powerful solar winds eventually stripped this primordial hydrogen layer away into space within the first 100 million years.

2. The secondary atmosphere ($\sim$ 4.5 to 3.8 Gy ago): As the planet cooled and a rock crust formed, rampant volcanic outgassing and asteroid impacts created a new atmosphere. While it was mostly dominated by water vapor (H_2O), carbon dioxide (CO_2), and nitrogen (N_2), it still retained small to moderate amounts of free H_2 gas.

   Scientists refer to this early environment as a "reducing" or "weakly reducing" atmosphere. Because there was no free oxygen (O_2), hydrogen gas could freely exist alongside other hydrogen compounds like methane (CH_4) and ammonia (NH_3) without immediately exploding or combusting into water.

   For a long time, scientists thought H_2 bled off into space instantly. However, modern atmospheric models (such as research from the University of Colorado Boulder) suggest that hydrogen escaped much slower than previously assumed. The early atmosphere may have consistently maintained anywhere from trace amounts up to significantly higher percentages of hydrogen gas over hundreds of millions of years.

   This high presence of hydrogen is crucial for the origin of life. A hydrogen-rich, reducing environment makes it much easier for chemical reactions to organically synthesize amino acids and prebiotic molecules the fundamental building blocks of the first living cells.

3. NH_3 (ammonia) molecules were present in Earth's "pre-Hadean" primordial atmosphere, but only for a very brief window before being rapidly destroyed. The period before the Hadean eon (prior to 4.56 Gy ago) corresponds to the accretion phase and the magma ocean stage of the proto-Earth. During this violent era, the behavior of ammonia depended heavily on the planet's evolving state.

4. The nebular influx (the primary atmosphere): As Earth was accumulating its mass from the solar nebula, its gravity briefly captured a primary atmosphere composed of light gases directly from space. This proto-atmosphere was deeply reducing and heavily mirrored the gas giants like Jupiter. Hydrogen (H_2), helium, methane (CH_4), and ammonia (NH_3) dominated this transient gas envelope.

5. The magma ocean phase (the outgassed atmosphere): As protoplanets and giant asteroids slammed into Earth culminating in the Moon-forming impact the entire planet melted into a glowing ball of magma. The primary solar nebula atmosphere was completely stripped away by these energetic impacts and intense early solar wind. A secondary atmosphere was immediately baked out of the molten rocks.

   Ammonia was present but as trace amounts. As gases erupted from the ultra-hot mantle, nitrogen was primarily released as stable dinitrogen gas (N_2). However, because the very early mantle was still chemically "reduced" (lacking oxygen), a notable fraction of nitrogen was outgassed as volatile NH_3.

6. Ammonia disappeared quickly: By the time the Hadean eon officially began (marked by the cooling and solidification of Earth's crust), neutral ammonia had practically vanished from the atmosphere. It faced two irreversible destructive mechanisms. The young Sun emitted ferocious ultraviolet (UV) radiation. Lacking an ozone layer, these UV rays split atmospheric NH_3 apart into nitrogen and hydrogen gases within a few million years. The

light hydrogen escaped directly into space. Ammonia is incredibly soluble in water. As soon as the Earth cooled enough for steam to condense into the first oceans, any remaining atmospheric ammonia dissolved into the water, stripping it cleanly from the air.

TGD inspired comments

1. According to the standard narrative, trimordial atmosphere: H_2 and ^4He from the solar wind (4.6 to 4.5 Gy ago). The secondary atmosphere ($\sim$ 4.5 to 3.8 Gy ago) would have been (weakly) reducing and the basic ingredients of the Miller-Urey process (H_2, CH_4, H_2O and NH_3) were stable enough to allow it in the time window 4.4-4.3 Gy. NH_3 was present in trace amounts.

2. In the TGD Universe, the emergence of the Moon about 4.5 Gy ago, would have thrown out the surface layer of the Earth and primary atmosphere with it and made the surface of the Earth a glowing plasma. This would have induced a compression as a recoil effect leading to the formation of Pollack silicate with 8 times higher density in the maximal contraction. The presence of surface oceans immediately after this event does not look plausible, which suggests that underground oceans were formed in the interior and the Urey-Miller process took place there. The creation of ammonium requires the splitting of N^2 molecules in the underground oceans and lightnings arriving along gravitational monopole flux tubes might have made this possible

1. Pressure and temperature during Hadean phase

During the Hadean eon (4.6 to 4.0 Gy ago), Earth's atmospheric pressure was immensely high ranging from roughly 27 to over 100 atmospheres (bars). This extreme pressure created a massive greenhouse effect and raised the boiling point of water, allowing liquid oceans to exist despite surface temperatures exceeding 200°C.

1. Atmospheric composition: The dense primordial atmosphere was primarily composed of carbon dioxide (CO_2), water vapor (H_2O), and hydrogen.

2. Ocean stabilization: The heavy atmospheric blanket acted like a pressure cooker. Because pressure increases the boiling point of water, liquid oceans could survive and cycle under extremely hot conditions.

3. Magma oceans: Earlier in the eon particularly after the catastrophic impact that formed the Moon the surface was dominated by molten magma. Massive volumes of volatile gases were constantly outgassed from the cooling mantle into the atmosphere, maintaining high pressure levels.The exact pressure fluctuated wildly as the planet transitioned from a molten state to one where a solid crust and oceans could eventually form.

The temperature during the Hadean eon was not static; it shifted from a molten inferno to a rapidly cooling planet. It can be broken down into three major phases:

1. The molten phase (4.6 to 4.5 Gy ago): Immediately following Earth's formation and the cataclysmic Moon-forming impact, surface temperatures exceeded 1,500°C to 2,000°C. The entire surface was a glowing, liquid sea of molten rock. Rocks and metals remained entirely liquefied, and no solid crust could form.

2. The heavy steam phase (4.5 to 4.4 Gy ago): As the initial heat from accretion began to radiate into space, the magma ocean solidified into a thin, rocky crust within a few million years. The Surface temperatures dropped to roughly 200°C to 230°C.

3. Liquid water paradox: Despite being well above the normal boiling point of water, the high atmospheric pressure kept water in a liquid state, pooling into the planet's very first highly acidic oceans.

4. The "cool early Earth" Phase (4.4 to 4.0 Gy ago). Evidence from ancient mineral grains (Zircons) suggests that by 4.4 Gy ago, the surface cooled dramatically, the temperature likely falling below 100°C.

During this time, the Sun was about 30% dimmer than it is today. Without a powerful atmospheric greenhouse effect trapping heat, the early Earth actually risked freezing over entirely. This is known as the faint young Sun paradox.

There were three primary sources of Hadean heat, which might have solved the paradox.

1. Accretion & impacts: Residual thermal energy from the kinetic energy of billions of colliding space rocks and planetesimals forming the Earth.
2. Radioactive decay: Radioactive isotopes (like Uranium, Thorium, and Potassium) were much more abundant and their decays released vast amounts of internal heat.
3. Greenhouse gases: A suffocating blanket of carbon dioxide and water vapor trapped solar radiation, insulating the cooling planet.

While classic models like the famous 1953 Miller-Urey origin of life experiment assumed Earth kept a thick, reducing methane-ammonia atmosphere deep into its history, modern astrobiological consensus indicates that by the Hadean eon, the atmosphere had transitioned into a "weakly reducing" mixture dominated by CO_2 and N_2.

TGD inspired comments

1. In the standard narrative, the solution of the liquid water paradox requires very high pressures to keep water in liquid phase above the normal boiling point. In the TGD based narrative the temperature and pressure in the underground water reservoirs inside Pollack silicate could be in the range allowed by biological life.
2. In the standard narrative, the solution of the faint Sun paradox requires mechanisms generating thermal energy and preventing its loss. Accretion and impacts and radioactive decays would have provided thermal energy. Greenhouse gases, in particular CO_2 would have induced greenhouse effect.

   The TGD based solution to the faint Sun paradox [L12] is that life evolved underground in underground oceans and the Earth interior provided the radiation keeping the temperature high enough and serving also as metabolic energy feed for photosynthesis. The evolving life would have been also shielded from the impacts and from cosmic rays and dramatic pressure fluctuations at the surface.

3.2 The emergence of the basic biomolecules in reducing environment

A hydrogen-rich, reducing environment is exactly what many leading prebiotic chemistry theories such as the classic Oparin-Haldane hypothesis and the Miller-Urey experiment require to kickstart the formation of life's fundamental building blocks. In this kind of environment, simple molecules like methane, ammonia, and hydrogen are highly reactive.

When energized by heat, ultraviolet light, or lightning, these gases readily form amino acids, sugars, and nucleotide bases. Here is how modern science views these reducing environments and where this chemistry is thought to happen:

1. Classic models simulated a reducing atmosphere rich in CH_4, NH_3, H_2, and H_2O. Without free oxygen (which destroys these delicate molecules through oxidation), these gases can synthesize amino acids and prebiotic molecules efficiently.
2. Today, many scientists look to deep-sea alkaline hydrothermal vents (like the "Lost sity" field). These environments are naturally rich in hydrogen (H_2) gas and continuously supply the chemical energy and catalytic surfaces needed to drive organosynthesis in the absence of sunlight.

3. Alternatively, reducing conditions in the early solar nebula may have synthesized these molecules in space, delivering them to early Earth via comets and meteorites.

TGD inspired comments

1. Standard narrative allows us to consider alkaline hydrothermal vents as environments making possible the organic synthesis via the Miller-Urey pathway. In the TGD framework, Miller-Urey process could be realized in underground water reservoirs in the Pollack phase. The situation would resemble that inside cells, and DNA and RNA molecules.
2. Ions are necessary for life and living matter consists of cold plasmas. TGD suggests that the evolution of the plasmoid life in the upper atmosphere could have preceded the evolution of chemical life in the interior of the Earth [L11]. Plasmoids could have been transferred to the Earth in thunderstorms as ball lightnings and would have provided the ions needed by the biochemical life.

3.2.1 Examples of oxidation

Oxidation of simple organic molecules involves increasing their oxygen content, decreasing their hydrogen content, or losing electrons. In chemistry, this process often moves a molecule from a highly reduced state (like methane) to a fully oxidized state (like carbon dioxide). Here are the most common examples of the sequential oxidation of simple organic molecules, categorized by their starting structures.

1. The Methane oxidation pathway

The classic example of sequential oxidation involves single-carbon (C1) compounds. Each step represents a higher oxidation state for the carbon atom:

1. Methane (CH_4) to Methanol (CH_3OH): This introduces a single oxygen atom into the fully reduced hydrocarbon.
2. Methanol (CH_3OH) to Formaldehyde (CH_2O): The molecule loses two hydrogen atoms, creating a carbon-oxygen double bond.
3. Formaldehyde (CH_2O) to Formic Acid ($HCOOH$): Another oxygen atom is inserted, converting the aldehyde into a carboxylic acid.
4. Formic Acid ($HCOOH$) to Carbon Dioxide (CO_2): The final oxidation step removes the remaining hydrogens, leaving carbon in its highest oxidation state (+4).

2. The ethane and ethanol Pathway For two-carbon (C2) chains, oxidation follows a similar progression but creates different functional groups:

1. Ethane (C_2H_6) to tthanol (C_2H_5OH): A hydrocarbon is oxidized into a primary alcohol.
2. Ethanol (C_2H_5OH) to acetaldehyde (CH_3CHO): The alcohol loses hydrogen (dehydrogenation) to become an aldehyde.
3. Acetaldehyde (CH_3CHO) to acetic acid (CH_3COOH): The aldehyde gains an oxygen atom to become the main component of vinegar.

3. Other Common Organic Oxidations

1. Organic molecules can also oxidize by forming rings, losing specific hydrogen pairs, or breaking bonds:
2. Primary alcohols to barboxylic acids: Direct, strong oxidation skips the stable aldehyde phase entirely.
3. Secondary alcohols to ketones: Oxidizing an alcohol like Isopropanol yields Acetone.
4. Glucose combustion: In living cells, the sugar Glucose ($C_6H_{12}O_6$) is oxidized by oxygen (O_2) to produce CO_2, water, and energy.

3.2.2 Miller-Urey pathway

The famous Miller-Urey experiment (conducted in 1952 and published in 1953) used molecular hydrogen (H_2) as a foundational chemical ingredient to prove that the fundamental building blocks of life could form spontaneously from a completely non-living, primitive environment.At the time, scientists Harold Urey and Stanley Miller operated on the "Oparin-Haldane hypothesis," which argued that early Earth possessed a highly "reducing" (hydrogen-rich) atmosphere with zero free oxygen.

Hydrogen gas played a critical role in the experiment's design, chemical pathways, and ultimate success:

1. Recreating the reducing atmosphere

Miller constructed a closed, sterile loop of borosilicate glass flasks to isolate his artificial environment. After vacuuming out all modern atmospheric air (to ensure no O_2 was present), he injected a specific gas mixture to represent the Hadean atmosphere:

Molecular Hydrogen (H_2) 100 mmHg of pressure.
Methane (CH_4) 200 mmHg.
Ammonia (NH_3) 200 mmHg.
Water Vapor (H_2O) boiled continuously from a lower flask to simulate evaporation from early oceans.

By filling the system with H_2 gas and other hydrogen-heavy molecules, Miller recreated a highly unstable, electron-donating chemical environment.

2. Breaking the hydrogen and nitrogen molecules (the lightning phase)

The gases were funneled into a large 5-liter atmospheric chamber equipped with two tungsten electrodes.

Miller fired continuous electrical sparks across the gap to simulate ancient lightning storms. This electrical energy tore apart the tight atomic bonds of the gases, splitting the stable H_2, CH_4, and NH_3 molecules into a chaotic soup of highly reactive free radicals ($H\cdot$, $\cdot CH_3$, $\cdot NH_2$).

3. Hydrogen frives the synthesis of life's building blocks

Because there was no oxygen to instantly combust these radicals back into H_2O or CO_2, the hydrogen-dense fragments were forced to recombine with each other into increasingly complex shapes. The chemical cascade happened in rapid steps:

1. The shattered hydrogen and carbon atoms first combined into volatile intermediaries like hydrogen cyanide (HCN) and formaldehyde (H_2CO).
2. These gases passed through a cooling condenser, turning into "rain" that washed down into the simulated ocean trap.
3. In the liquid pool, the HCN and aldehydes reacted directly with ammonia. Within just one week, this completely inorganic, hydrogen-rich soup organically synthesized several different amino acids (including glycine and alanine), which are the essential structural components of proteins.

Decades after the experiment, planetary models suggested Earth's early atmosphere might have been "weakly reducing" (mostly CO_2 and N_2) rather than heavily methane/ammonia-based. However, modern geology has shown that local hydrogen-rich environments were still incredibly common such as volcanic plumes bursting out of the early crust, or hydrothermal vents on the ocean floor, confirming that Miller's hydrogen chemistry was remarkably accurate for how life likely began.

TGD inspired comments

This raises several TGD inspired questions:

1. The proposal that early life developed in water reservoirs inside Pollack silicate suggests that the role of the Pollack effect [L27], transferring protons to the magnetic body of the water as dark protons with large h_{eff}, was central.

2. Metabolism without enzymes has been indeed observed recently to occur in the soil [I1] [L34]? Did the Pollack effect make possible metabolism, and more generally biocatalysis, without enzymes. In the TGD based model of photosynthesis and cellular respiration, the energy is indeed transferred as dark protons generated by the Pollack effect and liberated by the reverse Pollack effect.

3. Did Pollack effect make possible analogs of procells as water droplets with the analog of membrane potential between interior and exterior. The interiors of protocells would have been stable negatively charged exclusion zones (EZs) created by the Pollack effect.

4. The proposal is that dark DNA and RNA assignable to the magnetic body of water realized the genetic coded in terms of the icosa tetrahedral tessellation (ITT) of the hyperbolic 3-space H^3 [L26]. Were they already present and guided the evolution and eventually paired with ordinary RNA and DNA? What was the role of the water superclusters, which seem to have a close relationship with icosa tetrahedral tessellation of hyperbolic 3-space H^3 [L33], in the early evolution?

4. Constraints on pressure in Miller-Urey process

The Miller-Urey process bounds early Earth's surface pressure to roughly 1 atmosphere (atm) or lower for optimal prebiotic organic synthesis. While the experiment was originally designed to test chemical composition rather than barometric pressure limits, the gas laws, thermodynamics, and plasma physics governing the process impose a strict upper bound on surface pressure.

1. Spark discharge efficiency ($\leq$ 5 atm): The Miller-Urey experiment relies on electrical arcs to simulate lightning and rip apart molecular bonds. According to Paschen's Law, the voltage required to create a spark increase linearly with pressure. If Earth's surface pressure were significantly higher (e.g., 5 to 10 atm), natural lightning would have a much harder time breaking the dense air down into plasma.

   High atmospheric pressures prevent the gas molecules from shattering into the free radicals necessary to synthesize amino acids. Therefore, the process functions effectively only under a relatively low-pressure threshold, typically under 1 to 5 atm.

2. In the original experimental design pressure was in the range $\sim$ 0.7 to 0 atm: When Stanley Miller loaded the gases into his glass apparatus, he explicitly bounded the total pressure to mimic a near-modern surface atmosphere once heated. He added 100 mmHg of H_2, 200 mmHg of CH_4, and 200 mmHg of NH_3.

   When the liquid water was boiled, the continuous injection of water vapor pushed the total operating internal pressure right around 760 mmHg (0 atm) Laboratory safety protocols for recreating the process today dictate keeping total pressures below 1 atm, as overpressurization prevents the synthesis reactions and increases explosion risks.

3. The liquid ecean trap ($\geq$ 0.006 atm) was present. The Miller-Urey mechanism cannot function in a vacuum or an ultra-thin atmosphere (like modern Mars). The process requires a continuous water cycle: boiling oceans, condensation, and rain. The generated amino acids must immediately wash out of the spark chamber into a liquid ocean trap; otherwise, the continuous electrical sparks would destroy the delicate organic compounds they just made. For liquid oceans to stably exist on the surface of the Earth without instantly boiling away into space, the atmospheric pressure must stay above the triple point of water (0.006 atm).

To synthesize amino acids via the Miller-Urey pathway, the atmospheric pressure at the surface of Earth must fit into a stable window: 0.01 atm $\leq$ surface pressure $\leq$ 5 atm

5. At what time the Urey-Miller process became possible? The chemical and physical conditions required for the Miller-Urey process first became possible on Earth approximately 4.4 to 4.3 Gy ago, during the early Hadean eon. The timeline of when the process became viable is dictated by a sequential "checklist" of global planetary conditions:

1. Liquid water oceans (the target: $\sim$ 4.4 Gy ago): The Miller-Urey process requires a liquid water loop to evaporate into the atmosphere and act as a safe "trap" to catch and preserve newly formed amino acids from being destroyed by lightning.

2. The timing: Earth's surface was a scorching magma ocean immediately after formation ($\sim$ 4.54 Gy ago). Geochemical evidence from ancient Jack Hills zircon crystals proves that Earth's crust cooled enough for the very first liquid water oceans to condense by 4.4 Gy ago.

3. Atmospheric pressure stabilization ($\sim$ 4.4 to 4.3 Gy ago): the process fails if the atmosphere is too dense (preventing lightning sparks) or too thin (causing the water to instantly boil away into space). Once the main phase of the heavy bombardment slowed slightly and the global steam atmosphere condensed into the oceans, the global atmospheric pressure settled into the stable atmosphere window necessary for efficient lightning-driven plasma chemistry.

4. Peak hydrogen & reducing volatiles ($\sim$ 4.4 to 4.0 Gy ago): The experiment requires a "reducing" or hydrogen-rich environment (H_2, CH_4, NH_3) to force organic molecules to synthesize: This exact chemical window was widest between 4.4 and 4.0 Gy ago. During this era, global volcanic outgassing and a process called serpentinization (water reacting with the early iron-rich seafloor) pumped massive amounts of molecular hydrogen gas directly into the lower atmosphere.

5. The closing of the window ($\sim$ 3.8 Gy ago):

   The conditions that made the Miller-Urey process possible did not last forever. By 3.8 Gy ago (the start of the Archean eon), the Earth's atmosphere transitioned away from heavy hydrogen compounds toward a neutral mix dominated by carbon dioxide (CO_2) and nitrogen (N_2).

   In a pure CO_2 environment, the classic Miller-Urey spark reaction stops producing amino acids efficiently. Therefore, the perfect "prime time" for Miller-Urey chemistry on the surface of Earth was a roughly 400-million-year window between 4.4 and 4.0 Gy ago.

3.3 Nitrogen fixing problem

3.3.1 The role of volcanoes in early nitrogen fixing

As explosive volcanoes erupted, they ejected massive plumes of ash, rock, and gas. The intense friction between these churning particles generated enormous static electrical charges, triggering frequent and concentrated volcanic lightning.

Volcanic lightning would fix nitrogen. The process relies on extreme physical energy and a chain of rapid chemical reactions inside a volcanic plume: [ash particle friction] $\rightarrow$ [volcanic lightning ($\sim$ 1000°C)] $\rightarrow$ [N_2 bonds break] $\rightarrow$ [reaction with O/H]$\rightarrow$ [nitrates & nitrites]. Breaking of the triple covalent bond having energy of 9 eV between nitrogens requires energy. The electrical arcs of lightning reached temperatures around 3,000°C, which corresponds to a thermal energy of .4 eV. The energy of nitrogen bonds is by factor 22.5 higher and the argument is that thermal distribution allows sufficiently many photons with energy about 9 eV. This extreme heat provided the high energy required to tear apart the strong triple bonds of dinitrogen (N_2) gas.

Once split, the highly reactive, free nitrogen atoms immediately bonded with surrounding atmospheric components. In the early Earth's CO_2-rich atmosphere, they formed nitrogen oxides (NO_x). These gases reacted with atmospheric moisture to create nitric acid, which fell back to Earth via the rail of the lightning. Upon hitting the ground, the acid reacted with surface minerals to form stable nitrates (NO_3^-) and nitrites (NO_2^-) soluble salts that early life forms could easily absorb.

1. Volcanic lightnings Volcanic lightning (often called a "dirty thunderstorm") is a dramatic

electrical discharge that occurs inside a volcanic eruption plume. While it looks exactly like regular atmospheric lightning, it is entirely self-generated by the volcanic column. Instead of relying purely on ice crystals like a normal thunderstorm, a volcanic plume acts as a massive static-electricity generator driven by exploding rock and ash. The phenomenon develops across three distinct geographic zones within the plume, each relying on different physics:

1. The vent zone: Fragmentation Charging: Deep inside the volcanic throat, expanding gases shatter liquid magma into tiny dust and ash particles. The physical tearing apart of the rock naturally breaks chemical bonds, leaving the newly formed ash grains with built-in positive or negative electrical charges before they even touch the open air. This causes small, constant, short-lived electrical snaps right at the mouth of the crater.

2. Triboelectric charging in the near-nent plume: As the violent, dense column of ash shoots into the sky, billions of rock particles scrape, bounce, and smash into each other at supersonic speeds. For over a century, physicists wondered how identical particles of silicon dioxide (SiO_2) could transfer charge, since identical materials shouldn't exchange electrons. A landmark study published in Nature solved the mystery: high magmatic heat causes trace airborne carbon molecules to coat the ash in a fine atomic layer. This carbon layer acts as a chemical bridge that breaks symmetry and allows massive triboelectric (frictional) charging to occur during collisions.

   Heavy particles and lighter dust travel at different speeds due to aerodynamics, neatly separating the positive and negative charges into different areas of the cloud. When the voltage difference between these areas grows too high, the air snaps, generating massive lightning bolts.

3. Ice crystallization (the traditional nechanism) in the upper plume: If the volcanic column is energetic enough to punch high into the cold stratosphere (above 5 kilometers), the water vapor trapped in the volcanic gas rapidly freezes into ice. At this altitude, the volcano transitions into a traditional thunderstorm engine. The rising volcanic ice crystals crash into falling hail and ash. This creates the largest, most continuous, and longest-lasting lightning displays. During the 2022 Hunga Tonga submarine eruption, this exact ice-ash mix in the upper atmosphere generated a record-breaking 25,508 lightning strikes in just 5 minutes!

2. How deep are the volcanoes?

When discussing how "deep" a volcano is, geologists look at two distinct measurements: the height of the physical volcano cone on the surface, and the depth of the underground magma plumbing system feeding it.On the early Earth (the Hadean and Archean eons), both measurements were vastly different from what we see today.

1. Magma source depth: ultra-deep plumbing: In the modern world, most volcanic magma chambers sit relatively shallowly within the crust, about 5 to 15 kilometers beneath our feet. On the early Earth, the planet's interior was up to 200°C to 300°C hotter than it is today. This extreme heat completely altered the magma source depths: Hadean magma oceans (4.5 Gy ago): Immediately after Earth formed, the "volcano" was essentially the entire planet. A global magma ocean cascaded down into the upper mantle to a crushing depth of 400 to 1,000 kilometers.

   Deep mantle plumes (4.4 to 4.0 Gy ago): As the primitive crust solidified, localized volcanoes began to form. Because the early crust was thick, hot, and lacked modern moving tectonic plates, magma could not easily seep through shallow cracks. Instead, massive, high-temperature "mantle plumes" blasted straight up from deep chemical traps in the mantle between 330 and 410 kilometers deep to punch through the surface.

2. The volcanic cones: squat, heavy, and underwater: Because of how this deep magma erupted, the physical volcanic mountains on the surface did not look like the towering, steep peaks of Japan's Mount Fuji or Italy's Mount Vesuvius:

3. Komatiite overflows: The early, ultra-deep mantle magmas were a specialized rock type called komatiite. Because these magmas were extremely hot and iron-rich, they had a very low viscosity. They were as runny as liquid olive oil or warm asphalt.

4. The shape: Instead of building tall, pointy cones, the runny lava spread flatly across thousands of kilometers, building wide, gently sloping shield volcanoes or immense flat volcanic plains (similar to the modern Deccan traps in India but on a global scale).

5. Deep submarine eruptions: Because the early ocean covered nearly the entire planet, the vast majority of these volcanoes were completely submarine, erupting under 2,000 to 4,000 meters of ocean water. The crushing weight of the ocean water flattened the eruptions even further, preventing explosive ash clouds from forming until volcanic islands finally broke the surf later in the Hadean eon.

3. Why volcanic lightning was essential for early life?

While standard thunderstorms also fix nitrogen, volcanic lightning was uniquely equipped to jumpstart the biosphere for several reasons:

1. Massive yields: Researchers estimate that a single large, explosive volcanic event could fix up to 60 teragrams (60 million metric tons) of nitrogen. This is vastly more efficient than typical regional thunderstorms.
2. Concentrated delivery: Volcanoes deposited these life-giving nutrients directly into local ash beds and volcanic basins. These areas acted as stable, enclosed chemical cradles where prebiotic molecules could accumulate without being instantly diluted by the primordial ocean.
3. Geological proof: In a groundbreaking 2024 study published in PNAS, scientists analyzed ancient volcanic deposits in Peru and Turkey. They discovered massive, natural archives of nitrates matching the precise multi-isotopic signature of atmospheric lightning fixation, proving this process occurred on a massive scale.

Without these volcanic powerhouses generating a steady supply of fixed nitrogen, the organic building blocks of the first living cells would have lacked the critical components needed to reproduce and evolve.

TGD inspired comments

1. The energy 9 eV needed to break the nitrogen bond is suspiciously high as compared to the thermal energy of .4 eV assigned with the lightning. This because the thermal distribution is Gaussian around the thermal energy. If the lightning involved a transfer of charged particles and photons along monopole flux tubes much higher energies were possible and would make it easier to understand the splitting of N_2. The ionization of atoms in electrolytes involves a similar problem. Ohmic currents do not allow acceleration of electrons and ions to the energeis associate
2. A connection with the plasmoid life, which could have been predecessor of the organic life, is suggestive. Plasmoids could have delivered the basic organic ions from the upper atmosphere to the surface of the Earth [L11].
3. TGD suggests also the possibility of quartz life [L20]. One could say that Pollack silicate would actually provide its realization in the interior of the Earth.

3.3.2 Biological fixing of Nitrogen

Biological nitrogen fixation evolved because early Earth faced a severe nutrient crisis. As the planet cooled and volcanic activity stabilized, the massive abiotic production of nitrates via volcanic lightning ceased to meet the demands of a growing microbial population.

To survive this "nitrogen famine," early anaerobic bacteria evolved a way to break the triple bond of dinitrogen (N_2) internally. They accomplished this by repurposing existing metabolic tools into a single, revolutionary protein complex: nitrogenase.

1. The precursor: Molecular Exaptation (3.5 to 3.2 Gy ago): Microbes did not build the nitrogen-fixing machinery from scratch. Instead, they used exaptation a process where an existing cellular tool is adapted for a completely new function.

   The blueprint: Nitrogenase evolved from primitive maturase-like proteins. These ancestral proteins were already used by early microbes to build internal metal-sulfur clusters or process basic gases like hydrogen.

The metal advantage: The early oceans were dense with dissolved iron (Fe^{2+}). Early microbes routinely used iron-sulfur compounds to transfer electrons. Genetic mutations allowed these iron-rich proteins to bind with tiny, stable gaseous molecules like N_2.

2. The birth of the nitrogenase enzyme: The result of this evolution was nitrogenase, which remains the only biological engine on Earth capable of breaking down atmospheric nitrogen. It developed as a two-part molecular machine:

   The Fe-protein (the motor): This component uses cellular energy (ATP) to pump electrons down a molecular chain.

   The MoFe-Protein (the cutter): This component holds a specialized metal core often containing molybdenum (Mo) and iron (Fe) that acts as a chemical vice. It traps the N_2 molecule and iteratively forces electrons and protons into it until the triple bond snaps, producing two molecules of bioavailable ammonia (NH_3).

3. The "bacteria-rirst" horizontal spread: Recent genomic mapping of more than 30,000 microbial genomes has rewritten how this trait spread across the tree of life:

   (a) The origin: Current phylogenetic data strongly supports the bacteria-first hypothesis. The cluster of six core genes required for nitrogen fixation (nif genes) first developed inside ancient anaerobic bacteria.

   (b) Horizontal gene transfer: Because fixing nitrogen offered an immense evolutionary advantage, these nif gene clusters were frequently swapped between entirely different species through horizontal gene transfer (microbial gene sharing). This allowed ancient methane-producing Archaea to rapidly acquire the trait from Bacteria.

3.4 Emergence of photosynthesis and the Great Oxygenation Event

The emergence of photosynthesis and oxygen based life was a catastrophe for the existing bacterial life forms but led eventually to the generation of multicellulars.

3.4.1 Emergence of photosynthesis

Energy revolution meant profound changes in metabolism.

1. Organisms evolved aerobic metabolism, utilizing oxygen as a terminal electron acceptor to break down nutrients. Breathing oxygen yields up to 18 times more energy (ATP) than anaerobic fermentation from the same amount of food.

2. This massive surge in free biological energy allowed life to move past simple single-celled structures. It directly paved the way for the development of mitochondria, multicellular organisms, and eventually, complex animal ecosystems.

3. As oxygen levels rose in the atmosphere, solar radiation converted some of it into ozone (O_3). This formed the ozone layer, which blocked lethal ultraviolet (UV) rays and ultimately allowed life to safely leave the oceans and colonize dry land.

The oxygen on Earth came from water molecules (H_2O), split apart by a revolutionary biological process called oxygenic photosynthesis. Before this occurred, virtually all of Earth's oxygen was chemically locked away inside compounds like water and carbon dioxide (CO_2), leaving no free oxygen (O_2) gas in the atmosphere. The transition to a free-oxygen atmosphere between 7 and 3.5 Gy ago occurred when a group of single-celled marine microbes called cyanobacteria (often called blue-green algae) evolved a new metabolic trick. While earlier microbes used solar energy to split molecules like toxic hydrogen sulfide (H_2S), cyanobacteria evolved the unique machinery to utilize liquid water as a fuel source instead.

1. Using the power of sunlight, these tiny organisms performed a fundamental chemical reaction:Carbon Dioxide + Water (H_2O) + Sunlight $\rightarrow$ Sugars (Energy) + Oxygen Gas (O_2). The Hydrogen from the water molecule was kept by the bacteria and combined with carbon to create sugars, which

served as their food. The Oxygen left over from the broken water molecules was completely useless to the bacteria. They discarded it into the surrounding oceans as a toxic waste product.

2. Even though cyanobacteria pumped oxygen into the oceans for hundreds of millions of years before the GOE, the gas did not immediately enter the atmosphere. Earth possessed massive environmental "sinks" that soaked up the gas as fast as it was produced:

   (a) The iron sink: The ancient oceans were thick with dissolved iron. The early oxygen immediately reacted with this iron, creating rust that fell to the sea floor (forming the Banded Iron Formations mentioned earlier).

   (b) The methane sink: Any oxygen escaping into the air reacted with abundant atmospheric methane, converting it into carbon dioxide and water.

   The Great Oxygenation Event (GOE) finally occurred around 2 Gy ago when cyanobacterial populations boomed, eventually saturating and overwhelming these natural planetary sinks. With nowhere else to react, the discarded oxygen began accumulating directly into the atmosphere.

3.4.2 Evidence for GOE

Evidence for the GOE, believed to have occurred roughly 4 to 1 Gy (a more stringent estimate is 2.2-2 Gy ago) ago comes from geological and geochemical markers left in ancient rock records. Before this event, Earth's atmosphere and water reservoires (assumed to be oceans in the standard view) were virtually devoid of free oxygen. The most conclusive physical evidence for this shift includes:

1. Mass-independent sulfur isotope (S-MIF) data: This is considered the strongest evidence. In an oxygen-free atmosphere, ultraviolet (UV) light breaks down sulfur gases, leaving behind an irregular (non-zero) isotope signature. These signals are abundant in rocks older than 4 Gy, but they disappear entirely after $\sim$ 3 Gy, indicating that newly formed atmospheric ozone shielded the sulfur gases.

2. Loss of detrital pyrite and uraninite: Ancient river and delta deposits contain grains of minerals like pyrite (fool's gold) and uraninite. These minerals easily dissolve in the presence of oxygen. Their presence in river beds older than 4 Gy proves oxygen was nearly absent, while their disappearance in younger rocks shows oxygen levels had permanently spiked.

3. Banded iron rormations (BIFs): These are distinct, layered rock formations made of iron-rich minerals. They formed when dissolved iron in the ancient, oxygen-poor ocean encountered free oxygen produced by ancient cyanobacteria. The reaction created iron oxides (rust), which settled to the ocean floor. The massive BIF deposits found globally between 5 and 4 Gy ago point directly to massive amounts of oxygen being released into the oceans and subsequently rusting the seas.

4. Red beds and ancient soils (paleosols): As atmospheric oxygen climbed, it reacted with iron on land, causing soils and continental sandstones to turn red (due to iron oxidation, or rusting). The widespread appearance of these "red beds" post-dates the GOE, indicating oxygenic conditions on the ancient continents.

3.4.3 Consequences of GOE

The GOE fundamentally transformed life on Earth, acting simultaneously as Earth's first major mass extinction and the ultimate catalyst for complex evolution. Because oxygen is highly reactive, its sudden accumulation altered the biosphere in three profound ways:

1. Earth's first mass extinction. Before the GOE, Earth was dominated by anaerobic microbes. These organisms thrived in an environment completely devoid of oxygen. Free oxygen is highly electronegative and strips electrons from other molecules. To early anaerobic life lacking cellular defenses, oxygen acted as a corrosive, lethal poison that shredded cell membranes,

deformed proteins, and broke apart DNA. This toxic environment triggered a massive, global die-off. The surviving anaerobic organisms were forced to retreat deep underground, into hydrothermal vents, or under heavy sediment layers where oxygen could not reach them.

2. To survive in this newly "polluted" world, organisms had to adapt rapidly or perish. Surviving microbes evolved specific enzymes acting as antioxidants, such as catalase and superoxide dismutase, to safely neutralize harmful reactive oxygen species (ROS). Some organisms adapted existing compounds to fight off oxygen damage. For example, the hormone melatonin initially evolved over two Gy ago strictly as a powerful cellular antioxidant to protect life from oxygen toxicity.

3. An energy revolution and complex Life. While oxygen was initially a catastrophe, it eventually unlocked a massive biological advantage because of its high redox potential.

3.4.4 Mechanism of survival for bacteria

About 2.4-2.0 Gy ago, the GOE posed a near-fatal challenge to nitrogen-fixing life. Oxygen irreversibly destroys the iron-sulfur cores of nitrogenase. To prevent their newly evolved machinery from turning into rust, microorganisms evolved highly creative defense strategies:

1. Temporal isolation: Doing photosynthesis (which makes O_2) by day, and fixing nitrogen by night.

2. Spatial isolation: Developing thick, oxygen-impermeable cell walls called heterocysts specifically to house the enzyme.

3. Hyper-respiration: Consuming oxygen at the cell membrane at extreme speeds so it never reaches the interior.

4. Symbiosis: Hiding inside the root tissues of plants, using plant-made proteins (like leghemoglobin) to mop up excess oxygen.

3.4.5 How do nitrogen-fixing animals survive?

The very few specialized animals that host nitrogen-fixing bacteria use entirely different physiological workarounds to keep nitrogenase safe from their own oxygen-rich systems. Because animals cannot use their blood to create an anaerobic zone, the rare species that host nitrogen-fixing symbionts rely on strict physical isolation.

1. Gills isolation (shipworms): Marine shipworms feed entirely on wood, which lacks nitrogen. They house nitrogen-fixing bacteria (Teredinibacter turnerae) inside specialized cells in their gills. The bacteria are kept safely tucked inside intracellular compartments where local oxygen levels are kept low, completely isolated from the animal's main circulatory stream.

2. Deep gut anaerobiosis (termites): Termites rely heavily on nitrogen-fixing bacteria in their hindguts to survive on a wood-only diet. They protect the nitrogenase by utilizing the severe oxygen gradient of their digestive tract. The center of the termite hindgut is completely anaerobic (devoid of oxygen) because local microbes consume oxygen faster than it can diffuse inward, creating a safe zone for nitrogen fixation.

3. Marine clams (Lucinidae): Certain saltwater clams host nitrogen-fixing bacteria in their gill tissues. They survive by living deep inside marine mud where oxygen levels are naturally depleted, reducing the amount of oxygen the animal takes in from its environment.

3.4.6 How do plants survive?

Plants do not produce nitrogenase themselves, so they solve the oxygen problem by creating highly regulated, micro-aerobic "safe houses" for their symbiotic bacteria. The plant must perform a delicate balancing act: it must keep free oxygen concentrations low enough to protect the enzyme, yet deliver just enough oxygen to the bacteria so they can undergo cellular respiration and generate the massive amounts of ATP required to break down nitrogen. Plants solve this complex problem using a multi-layered defense strategy:

1. Variable oxygen diffusion barrier: Plants actively control how much oxygen can physically enter the root nodules where bacteria live.

2. Cortical barrier: The outer cell layer of the root nodule (the nodule parenchyma) is packed tightly with very few air spaces. If oxygen levels in the soil spike unexpectedly, the plant can rapidly adjust the permeability of this barrier. It does this by flooding the intercellular channels with glycoproteins or changing the water pressure (osmotic potential) of the cells, physically squeezing the entry paths shut to block gas diffusion.

3. Using Leghemoglobin as a precision oxygen buffer: Once inside the nodule, the plant relies on leghemoglobin a custom protein that gives healthy root nodules a distinct pink or red color. Leghemoglobin has an oxygen affinity roughly 10 times higher than the hemoglobin found in human blood. It instantly grabs free oxygen molecules floating in the cell cytoplasm.

4. Targeted delivery: By binding to free oxygen, it keeps the background concentration of toxic free oxygen incredibly low (in the nanomolar range). However, it unloads this oxygen directly to the bacterial electron transport chain, feeding their respiration without allowing the oxygen to wander off and destroy the nitrogenase.

5. Creating symbiosome membranes: The plant does not let bacteria roam freely inside its cells. The host plant wraps the bacteria in a specialized internal plant membrane called the peribacteroid or symbiosome membrane. This membrane acts as a strict cellular gatekeeper, regulating the exact flow of gases, ions, and carbon energy source (sugars) between the plant cell interior and the symbiont.

6. Relying on bacterial high-rate respiration: The plant takes advantage of the bacteria's own metabolic processes to keep oxygen levels down. Because fixing nitrogen takes immense energy, the bacteria burn carbohydrates provided by the plant at an incredibly fast rate. This hyper-active cellular respiration acts as a natural vacuum, consuming oxygen almost as fast as it crosses the cell boundary, preventing it from building up near the nitrogenase.

Comment: TGD view of metabolism. The role of Pollack effect.

3.5 The emergence of RNA, DNA and proteins

3.5.1 Standard narrative

According to the standard narrative, RNA emerged first, approximately 4.3 to 4.1 Gy ago, followed by the evolution of DNA between 4.0 and 3.8 Gy ago. Because molecular blueprints do not leave standard hard fossils, scientists use molecular biology and organic chemistry models to map this transition, dividing it into three distinct evolutionary epochs.

1. The prebiotic soup (4.4 to 4.3 Gy ago). Before actual genetic strands existed, raw chemical processes had to build the necessary parts. Following the types of pathways seen in the Miller-Urey process, the primitive atmosphere and hydrothermal vents synthesized simple sugars, phosphates, and nitrogen bases. Recent biochemical research indicates that the structural building blocks for both RNA and DNA actually formed together in this early prebiotic broth.

2. The RNA World (4.3 to 4.1 Gy ago). The scientific consensus leans heavily on the RNA World Hypothesis. This theory highlights that RNA was the very first hereditary molecule to emerge and organize.

   Modern life uses DNA to store data and proteins to do mechanical work. RNA is unique because it can do both. It can store genetic sequences and fold into 3D shapes called ribozymes that act like enzymes to speed up chemical reactions. Around 4.3 Gy ago, random chemical chains of RNA gained the ability to catalyze their own replication. This kicked off the very first stage of molecular Darwinian evolution on Earth. The ribosome the ancient cellular engine that builds proteins in every living creature today has a core active site made entirely of catalytic RNA rather than protein, preserving a structural fossil from this era.

3. The Takeover of DNA (4.0 to 3.8 Gy ago). As these primitive RNA-based life forms grew more complex, RNA's chemical limitations became a problem. RNA contains a highly reactive ribose sugar component, making the molecule fragile and prone to breaking apart easily.To safeguard their increasingly complex genetic instructions, early organisms evolved an enzyme path to modify the sugar, stripping away an oxygen atom to create Deoxyribonucleic Acid (DNA):

   (a) Removing the oxygen atom made the molecular backbone very stable, allowing genomes to grow vastly longer without degrading.

   (b) DNA naturally paired into a tightly zipped double helix. This protected the genetic code inside the strands and provided an automatic backup copy for fixing mutations.By 3.8 to 3.5 Gy ago, the transition was complete. DNA became the permanent, long-term hard drive for life, downgrading RNA to its modern role as the temporary messenger.

3.5.2 The TGD narrative about basic information molecules

The TGD based story differs [L34] from the standard narrative in many respects.

1. The new view of space-time identified as 4-surface in $H = M^4 \times CP_2$ and obeying holography = holomorphy vision (H-H) [L16, L23] predicts a slight failure of classical determinism although field equations are satisfied. The geometric correlates of cognition and cognitive consciousness itself can be assigned with this non-determinism. This non-determinism is present in all scales so that cognition and consciousness are universal.

2. H-H forces a new view of quantum, I call it zero energy ontology [L5] [K5], as the second essential element and solves the basic paradox of the quantum measurement theory and generalizes it to a theory of conscious experience. The prediction of a hierarchy of effective Planck constants h_{eff} implies that quantum coherence is possible in arbitrarily long scales. This is essential for understanding the coherent behavior of living matter not possible to understand in life-as-mere chemistry approach. The electric *resp.* gravitational Planck constant h_{em} *resp.* h_{gr} associated with corresponding classical long range fields are particular (maybe the only) instances of h_{eff}.

3. The new view of classical fields implies the notion of field body. For instance, magnetic body has monopole flux tubes as body parts [L14, L15]. Field body is characterized by a very large value of effective Planck constant h_{eff} serving as a measure of algebraic complexity and a a kind of IQ so that it naturally serves as controller of the biological body.

4. The notion of genetic code generalizes. There could be "dark" realizations of genetic code at the electric and gravitational magnetic body of the organism serving as controllers of the organism. The genetic code can be assigned to the so-called icosa tetrahedral tessellation (ITT) [L9, L26] of the hyperbolic 3-space H^3, which is completely unique in that it involves all 3 platonic solids (tetrahedron, octahedron and icosahedron having equilateral triangles as faces). This realization is universal and possible on all scales.

5. The realization of ITT at the space-time level is obtained by projecting the ITT to the space-time surface, and also 2- and 3-D realizations can be considered. This leads to the notions of dark DNA and RNA with codons realized as dark proton triplets. Dark DNA and RNA could have emerged at the same time could be also identical.

   The dark protons associated with their magnetic bodies would be produced by the Pollack effect and give them stable negative charges. Also cells are negatively charged and accompanied by dark protons or even ions at the magnetic body. Both genes and cells define evolutionary hierarchies with the values of gravitational and electric Planck constants [L28, L30] increasing with the cell size and length of the gene.

6. The recently discovered universal communications in living matter in a frequency range peaked around 2 Hz universal and starting from .5 Hz, could be based to the cyclotron transitions of dark DNA [L31]. For the endogenous magnetic field B_{end} assignable to monopole flux tubes deduced from the findings of Blackman [J1] predicts universal cyclotron frequency

of 1 Hz for DNA sequences. TGD strongly suggests a hierarchy of values of B_{end} coming as powers of 2. The dark DNA and RNA would control ordinary DNA and RNA by a signalling based on dark 3-N photons inducing sequences of 3N-resonances.

7. It is possible that ordinary RNA emerged first as a chemical representation of the universal genetic code. The presence of -OH in the ribose makes possible the Pollack effect and the realization of the genetic code for a single strand of RNA whereas for DNA missing -OH, both strands are required. Amino-acids do not have in general -OH groups so that they cannot have constant charge density so that they have the role of building bricks of biomatter.

3.5.3 How to solve the hen-egg problems of the standard view?

The standard view of the evolution of life is plagued by several hen-egg problems. [L4, L8].

1. Was RNA or DNA first? The emergence of dark DNA and RNA (possibly identical with dark DNA) solves this hen-egg problem and chemical RNA naturally precedes DNA. Proteins could have a role as catalysts for the generation of ordinary RNA and DNA that occurred later.

2. Did genetic code precede proteins or vice versa? ITT realization of the genetic code came naturally first and its chemical realization emerged later when proteins had evolved from the amino acids present already in the beginning, thanks to Miller-Urey pathway discussed in the Appendix.

   RNA molecules were not present in the primordial soup but individual RNA nucleotide precursors are generated in hydrothermal vents. The ordinary RNA molecules could have emerged from the pairing of dark RNA and ordinary RNA by multi-cyclotron resonance with dark RNA serving as a template. The ordinary RNA could in turn have served as a catalyst (ribozyme) for the formation of proteins, which in turn became building bricks and catalysts (enzymes).

   Could dark RNA (possibly identical with dark DNA) have led to the formation of proteins by cyclotron pairing with amino acids? Amino acids are not in general charged so that they do not have large electric Planck constant h_{em}. This does not favor this option.

3. Did metabolism precede basic biomolecules or vice versa? Quite recently I learned that oxygen metabolism is possible in soil from which life has been killed by irradiation as the production of CO_2 demonstrates. The TGD based explanation is in terms of the Pollack effect, which makes possible metabolism [L34].

4. Did biocatalysis precede proteins and RNA or vice versa. Biocatalysis is actually one of the mysteries of recent biology. TGD suggests a universal mechanism of biocatalysis based on the notion of monopole flux tubes labelled by h_{eff}. In biocatalysis, a catalyst and substrate molecule must find each other. This would be based on the reconnection of U-shaped monopole flux tubes associated with both. Multi-cyclotron resonance, analogous to the tuning of radio, would make the reconnection highly selective. After that a transition reducing the value of h_{eff} shortening the length of the flux tube would occur and bring the reactants together. The liberated energy would allow it to overcome the energy wall preventing the reaction otherwise. This mechanism also makes possible the immune system at the fundamental level based on recognition of bioactive molecules by cyclotron resonance at the fundamental level. This also provides an explanation for homeopathy. [K3].

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